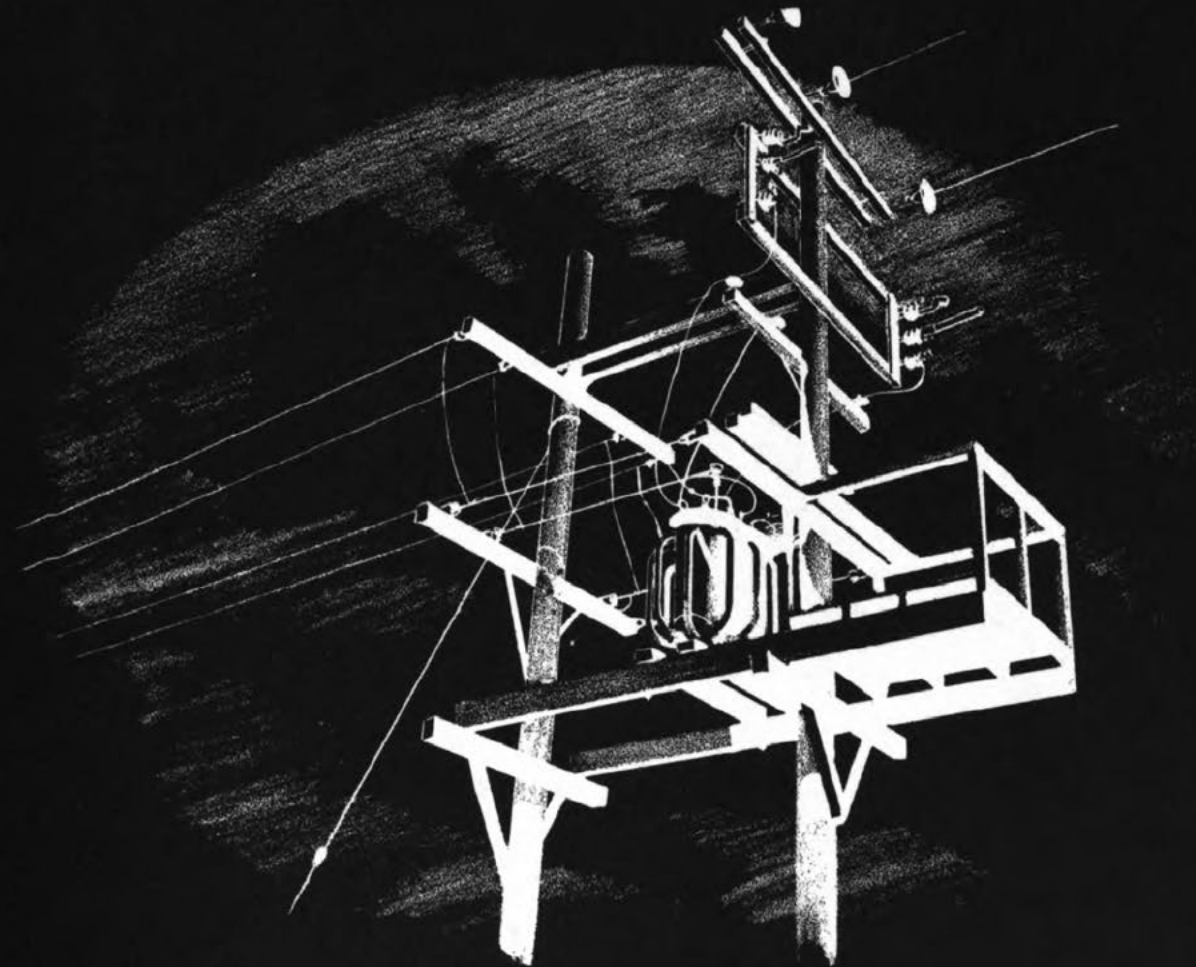

CONSTRUCTION ELECTRICIAN 1 & C

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE NAVPERS 10637-C

PREFACE

This book is intended to serve as an aid for men who are seeking to acquire the theoretical knowledge and operational skills required of candidates for advancement to the rates of Construction Electrician First Class and Chief Construction Electrician. As one of the Navy Training Courses, this book was prepared by the Training Publications Division, Naval Personnel Program Support Activity, Washington, D.C., for the Bureau of Naval Personnel. The Construction Electrician Schools, U.S. Naval Schools Construction, Port Hueneme, California, and the Naval Construction Training Unit, Naval Construction Battalion Center, Davisville, Rhode Island, provided technical assistance.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CREDITS

Illustrations indicated below are included in this edition of Construction Electrician 1 & C through the courtesy of the designated companies. Permission to use these illustrations is gratefully acknowledged.

Source	Figures
Daystrom Weston Incorporated Instruments Division	5-6; 5-8.
Ward Leonard Electric Company	4-12; 4-13
Webster Electric Company	8-28

READING LIST

NAVY TRAINING COURSES

Construction Electrician 3 & 2, NavPers 10636-E
Basic Electricity, NavPers 10086-A
Electricians Mate 1 & C, NavPers 10547

OTHER PUBLICATIONS

Seabee Planner's and Estimator's Handbook, NavDocks P-405

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Educational Services Officer.* A partial list of these courses applicable to your rate follows:

Number	Title of Course
B 781	Fundamentals of Electricity
B 885	Fundamentals of Radio
B 890	Principles of Practices of Radio Servicing

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*"Members of the United States Armed Forces Reserve Components, when on active duty, are eligible to enroll for USAFI courses, services, and materials, if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified in the active duty orders."

CHAPTER 1

PREPARING FOR ADVANCEMENT IN RATING

Those stripes on your arm show that you have been a Construction Electrician long enough to realize the importance of your rating to the Navy. They indicate that you have learned your job well and mark you as having served the Navy and as being skilled in the field of electrical equipment—both power and communications.

From your years of experience, you undoubtedly realize the amount of care and efficient workmanship demanded of the men in your rating. In a construction battalion, especially, efficient operation is closely related to efficient installation and maintenance procedures for electrical equipment. As a CE1 or CEC, you will have an opportunity and a responsibility to see that the men whom you supervise are meeting required installation and maintenance standards.

Previously, in studying for advancement, you have concentrated upon increasing your technical skills and developing the knowledge essential to those who work on electrical equipment.

Throughout your naval career, you must continue to study and to develop your knowledge and skills. As a CE1 or CEC, you have the additional responsibility of supervisory duties. A successful supervisor must be a leader, organizer, and teacher.

You are aware that you need actual experience to master a skill or a technique. You will find that you also need experience to become a good supervisor. But, just as you learned some of the fundamentals of electricity from textbooks, so you can learn of the principles of supervision from the experience of others. This text contains some of the technical aspects of your job and also some of the basic principles of good supervision.

The remainder of this chapter gives information that will help you in working for advancement in rating. It is strongly recommended that you study it carefully before beginning intensive study of the remainder of this training course.

REWARDS AND RESPONSIBILITIES

Advancement in rating brings both increased rewards and increased responsibilities. The time to start looking ahead and considering the rewards and the responsibilities of advancement is right now, while you are preparing for advancement to CE1 or CEC.

By this time, you are probably well aware of many of the advantages of advancement in rating—higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. By this time, also, you have probably discovered that one of the most enduring rewards of advancement is the personal satisfaction you find in developing your skills and increasing your knowledge.

The Navy also benefits by your advancement. Highly trained personnel are essential to the functioning of the Navy. By each advancement in rating you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. And second, you become more valuable as a person who can supervise, lead, and train others and thus make far reaching and long lasting contributions to the Navy.

In large measure, the extent of your contribution to the Navy depends upon your willingness and ability to accept increasing responsibilities as you advance in rating. When you assumed the duties of a CE3, you began to accept a certain amount of responsibility for the work of others. With each advancement in rating, you accept an increasing responsibility in military matters and in matters relating to

the professional requirements of the Construction Electrician rating.

You will find that your responsibilities for military leadership are about the same as those of petty officers in other ratings, since every petty officer is a military person as well as a technical specialist. Your responsibilities for technical leadership are special to your rating and are directly related to the nature of your work. Operating, maintaining, and building electrical facilities is a job of vital importance; it requires a special kind of supervisory ability and can only be developed by personnel who have a high degree of technical competence and a deep sense of personal responsibility.

Certain practical details that relate to your responsibilities for administration, supervision, and training are discussed in other chapters of this training course. At this point, let's consider some of the broader aspects of your increasing responsibilities for military and technical leadership.

YOUR RESPONSIBILITIES WILL EXTEND BOTH UPWARD AND DOWNWARD. Both officers and enlisted personnel will expect you to translate the general orders given by officers into detailed, practical on-the-job language that can be understood and followed even by relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their work properly. At the same time, you must be able to explain to officers any important needs or problems of the enlisted men.

YOU WILL HAVE REGULAR AND CONTINUING RESPONSIBILITIES FOR TRAINING. Even if you are lucky enough to have a highly skilled and a well trained electrical crew, you will still find that training is necessary. For example, you will always be responsible for training lower rated men for advancement in rating. Also, some of your best workers may be transferred and inexperienced or poorly trained personnel may be assigned to you. Or a particular job may call for skills that none of your personnel have. These and similar problems require you to be a training specialist who can conduct formal and informal training programs to qualify personnel for advancement and who can train individuals and groups in the effective execution of assigned tasks.

YOU WILL HAVE INCREASING RESPONSIBILITIES FOR WORKING WITH OTHERS. As you advance to CE1 and then to CEC, you will find that many of your plans and decisions affect a large number of people, some of whom are not in the electric shop and some of whom are not even in the electrical field. It becomes increasingly important, therefore, to understand the duties and responsibilities of personnel in other ratings. Every petty officer in the Navy is a technical specialist in his own field. Learn as much as you can about the work of other ratings, and plan your own work so that it will fit in with the overall mission of the organization.

AS YOUR RESPONSIBILITIES INCREASE, YOUR ABILITY TO COMMUNICATE CLEARLY AND EFFECTIVELY MUST ALSO INCREASE. The basic requirement for effective communication is a knowledge of your own language. Use correct language in speaking and in writing. Remember that the basic purpose of all communication is understanding. To lead, supervise, and train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

A second requirement for effective communication in the Navy is a sound knowledge of the Navy way of saying things. Some Navy terms have been standardized for the purpose of ensuring efficient communication. When a situation calls for the use of standard Navy terminology, use it.

Still another requirement of effective communication is precision in the use of technical terms. A command of the technical language of the Construction Electrician rating will enable you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms used in connection with the work of his own rating is at a disadvantage when he tries to read official publications relating to his work. He is also at a great disadvantage when he takes the written examinations for advancement in rating. Although it is always important for you to use technical terms correctly, it is particularly important when you are dealing with lower rated men; sloppiness in the use of technical terms is likely to be very confusing to an inexperienced man.

YOU WILL HAVE INCREASED RESPONSIBILITIES FOR KEEPING UP WITH NEW DEVELOPMENTS. Practically everything in the Navy—policies, procedures, equipment, publications, systems—is subject to change and development. As a CE1, and even more as a CEC, you must keep yourself informed about all changes

and new developments that might affect your rating or your work.

Some changes will be called directly to your attention, but others you will have to look for. Try to develop a special kind of alertness for new information. Keep up to date on all available sources of technical information. And, above all, keep an open mind on new construction methods and associated equipment. New types of equipment are constantly being designed and tested. If you look back over the history of construction battalions since the end of World War II, you will find that a number of important changes have occurred during this time. Work in the Antarctica has been a continuous development and cold weather construction methods have changed. The improvement in equipment and material design has helped our overall efficiency a great deal. There are new aids that have been developed that will allow the man in the field very little lost time in completing his assigned job. These things mentioned are but a few new developments that are helpful and indicate changes that could be made in the ever improving field of electricity.

REQUIREMENTS FOR ADVANCEMENT

In general, to qualify for advancement you must:

1. Have a certain amount of time in grade.
2. Complete the required military and professional training courses.
3. Demonstrate the ability to perform all the PRACTICAL requirements for advancement by completing the Record of Practical Factors, NavPers 760.
4. Be recommended by your commanding officer.
5. Demonstrate your KNOWLEDGE by passing a written examination based on (a) the military requirements for advancement and (b) the professional qualifications for advancement in the Construction Electrician rating.

Advancement in rating is not automatic. Meeting all the requirements makes you eligible for advancement but it does not guarantee your advancement. Some of the factors that determine which persons, out of those who take the examinations, will actually be advanced in rating are the scores made on the written examination, the length of time in service, the performance marks, and the quotas for the rating.

Remember that the requirements for advancement may change from time to time. Check with your division officer or with your training officer to be sure you have the most recent requirements when you are preparing for advancement and when you are helping lower rated men to prepare for advancement.

To prepare for advancement, you need to be familiar with (1) the military requirements and the professional qualifications given in the Manual of Qualifications for Advancement in Rating, NavPers 18068-A (with changes); (2) the Record of Practical Factors, NavPers 760; (3) appropriate Navy Training Courses; and (4) any other material that may be required or recommended in the current edition of Training Publications for Advancement in Rating, NavPers 10052. These materials are discussed later in the section of this chapter that deals with sources of information.

THE CONSTRUCTION ELECTRICIAN RATING

As a CE1 or CEC, you will be in a GENERAL RATING rather than in a SERVICE RATING. A general rating reflects qualifications in ALL aspects of an occupational field rather than in one aspect only. For example, a Construction Electrician in pay grade E4 or E5 is required to be proficient in only one phase of the CE rating—the wiring, power, telephone, or the shop phase. At the levels of E6 or E7, however, he is required to be competent in ALL phases of the CE rating. You advanced through one of the CE service ratings—CEW, CEP, CET or CES. Before advancing to pay grade E6, it is necessary for you to learn the essentials of the other service ratings. If you have specialized, for example in power, you must learn about the other three service ratings as well. Before you advance to the rate of chief, you must learn how to CROSS-TRAIN men in lower grades—that is, give them training in the service ratings in which they have not specialized in order that they may advance to the general rating.

Cross-training—that is, preparing men in service ratings for advancement to the general rating—is an important part of your training job. Before any of the CE2s (CEP, CES, CET, or CEW) can be advanced to CE1 they must all be familiar with the duties of the other service ratings.

The first step in setting up a program of cross-training is to make a careful study of the qualifications for advancement in rating. Suppose you are training a CEP2 for advancement to CE1. First of all, the man must be trained in all of the quals for CE1. In addition,

however, you will have to make sure that he is trained and checked out in all quals required for the other CE3 and 2 service ratings; EXCEPT in cases where quals are common to all the other service ratings.

After you have listed all of the CES, CET, and CEW 3 and 2 quals that the CEP2 must learn, but in which he is not checked out, group these quals into logical units of work or study. Some of the material can be learned by study of the appropriate training course. Other subjects can only be learned by practical experience. Whenever possible, use regular working situations and training situations. When formal training is required, plan it all out in advance so that you will be able to make the best use of the available time. Some of the information given in chapter 10 of this training course may be adapted to other training situations.

SCOPE OF THIS TRAINING COURSE

Before studying any book, it is a good idea to know the purpose and the scope of the book. Here are some things you should know about this training course:

It is designed to give you information on the professional (technical) qualifications for advancement to CE1 and CEC.

It must be satisfactorily completed before you can advance to CE1 or CEC, whether you are in the Regular Navy or in the Naval Reserve.

It is NOT designed to give you information on the military requirements for advancement to PO1 or CPO. Navy Training Courses that are specially prepared to give information on the military requirements are discussed in the section of this chapter that deals with sources of information.

It is NOT designed to give you information that is related primarily to the qualifications for advancement to CE3 and CE2. Such information is given in Construction Electrician, NavPers 10636-E.

The professional (technical) Construction Electrician qualifications that were used as a guide in the preparation of this training course were those promulgated in the Manual of Qualifications for Advancement in Rating, NavPers 18068-B, of June 1965. Therefore, changes in the Construction Electrician qualifications occurring after June 1965 may not be reflected in the information given in this training course. Since your major purpose in studying this training course is to meet the qualifications for advancement to CE1 or CEC, it is important for you to obtain and study a set of the most recent qualifications.

This training course includes information that is related to both the KNOWLEDGE FACTORS and the PRACTICAL FACTORS of the qualifications for advancement to CE1 and CEC. However, no training course can take the place of actual on-the-job experience for developing skill in the practical factors. The training course can help you understand some of the whys and wherefores, but you must combine knowledge with practical experience before you can develop the required skills. The Record of Practical Factors, NavPers 760, should be utilized in conjunction with this training course whenever possible.

This training course deals almost entirely with the technical subject matter of the Construction Electrician rating. Before studying these chapters, study the table of contents and note the arrangement of information. Information can be organized and presented in many different ways. You will find it helpful to get an overall view of the organization of this training course before you start to study it.

SOURCES OF INFORMATION

It is very important for you to have an extensive knowledge of the references to consult for detailed, authoritative, up-to-date information on all subjects related to the military requirements and to the professional qualifications of the Construction Electrician rating.

Some of the publications discussed here are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been entered.

BUPERS PUBLICATIONS

The BuPers publications described here include some which are absolutely essential for anyone seeking advancement in rating and some which, although not essential, are extremely helpful.

THE QUALS MANUAL.—The Manual of Qualifications for Advancement in Rating, NavPers 18068-B (with changes), gives the minimum requirements for advancement to each rate within each rating. The Quals Manual lists the

military requirements which apply to all ratings and the professional or technical qualifications that are specific to each rating.

The Quals Manual is kept current by means of numbered changes. These changes are issued more frequently than most Navy Training Courses can be revised; therefore, the training courses cannot always reflect the latest qualifications for advancement. When preparing for advancement, you should always check the LATEST Quals Manual and the LATEST changes to be sure that you know the current requirements for advancement in your rating.

When studying the qualifications for advancement, remember these three things:

1. The quals are the MINIMUM requirements for advancement to each rate within each rating. If you study more than the required minimum, you will of course have a great advantage when you take the written examinations for advancement in rating.

2. Each qual has a designated rate level—third class, second class, chief. You are responsible for meeting all quals specified for advancement to the rate level to which you are seeking advancement AND all quals specified for lower rate levels.

3. The written examinations for advancement in rating contain questions relating to the practical factors and the knowledge factors of BOTH the military requirements and the professional qualifications.

A special form known as the Record of Practical Factors, NavPers 760, is used to record the satisfactory completion of the practical factors, both military and professional, listed in the Quals Manual. This form is available for each rating. Whenever a person demonstrates his ability to perform a practical factor, appropriate entries must be made in the DATE and INITIALS columns. As a CE1 or CEC, you will often be required to check the practical factor performance of lower rated men and to report the results to your supervising officer.

The Record of Practical Factors should be kept by the division officer, company commander, or the appropriate supervising officer of each man in pay grade E-3 through E-8. A copy should be made available to each man for his personal record and guidance.

As changes are made periodically to the Quals Manual, new forms of NavPers 760 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement. Keep this in mind when you are training and supervising lower rated personnel. If a man demonstrates proficiency in some skill which is not listed in the CE quals but which falls within the general scope of the rating, report this fact to the supervising officer so that an appropriate entry can be made.

Upon transfer of personnel, the supervising officer's copy of the NavPers 760 is to be signed and inserted in the correspondence side of the enlisted service record for transfer with the man.

NAVPERS 10052.—Training Publications for Advancement in Rating, NavPers 10052, is a very important publication for anyone preparing for advancement in rating. This publication lists required and recommended Navy Training Courses and other reference material to be used by personnel working for advancement in rating. NavPers 10052 is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter following the NavPers number. When using this publication, be SURE you have the most recent edition by checking the edition date as well as the letter.

The required and recommended references are listed by rate level in NavPers 10052. It is important to remember that you are responsible for all references at lower rate levels, as well as those listed for the rate to which you are seeking advancement.

Navy Training Courses that are marked with an asterisk (*) in NavPers 10052 are MANDATORY at the indicated rate levels. A mandatory training course may be completed by (1) passing the appropriate Enlisted Correspondence Course based on the mandatory training course, (2) passing locally prepared tests based on the information given in the mandatory training course, or (3) in some cases, successfully completing an appropriate Navy school.

It is important to notice that all references, whether mandatory or recommended, listed in NavPers 10052 may be used as source material

for the written examinations, at the appropriate rate levels.

NAVY TRAINING COURSES.—Navy Training Courses are written for the specific purpose of helping personnel prepare for advancement in rating. Some courses are general in nature and are intended for use by more than one rating; others (such as this one) are specific to the particular rating.

Navy Training Courses are revised from time to time to bring them up to date. The revision of a Navy Training Course is identified by a letter following the NavPers number. You can tell whether a Navy Training Course is the latest edition by checking the NavPers number and the letter following the number in the most recent edition of the List of Training Manuals and Correspondence Courses, NavPers 10061 (revised).

There are three Navy Training Courses that are specially prepared to present information on the military requirements for advancement. These courses are:

Basic Military Requirements, NavPers 10054-A.
Military Requirements for Petty Officer 3 & 2, NavPers 10056-A.
Military Requirements for Petty Officer 1 & C, NavPers 10057-A.

Each of the military requirements courses is mandatory at the indicated rate levels. In addition to giving information on the military requirements, these three books give a good deal of useful information on the enlisted rating structure; how to prepare for advancement; how to supervise, train, and lead other men; and how to meet your increasing responsibilities as you advance in rating.

Some of the Navy Training Courses that may be useful to you when you are preparing to meet the professional qualifications for advancement to CE1 and CEC are discussed briefly in the following paragraphs. For a complete listing of Navy Training Courses, consult the List of Training Manuals and Correspondence Courses, NavPers 10061 (revised).

Basic Handtools, NavPers 10085-A. Although this training course is not specifically required for advancement in the Construction Electrician rating, you will find that it contains a good deal of useful information on the care and use of all types of handtools and portable power tools commonly used in the Navy.

Blueprint Reading and Sketching, NavPers 10077-B, contains information that may be of value to you as you prepare for advancement to CE1 and CEC.

Mathematics, vol. 1, NavPers 10069-B, and Mathematics, vol. 2, NavPers 10071-A. These two training courses may be helpful if you need to brush up on your mathematics. Volume 1, in particular, contains basic information that is needed for using formulas and for making simple computations. The information contained in volume 2 is more advanced than you will need for most purposes, but you may occasionally find it helpful.

Navy Training Courses prepared for other Group VIII (Construction) ratings are often a useful source of information. Reference to these training courses will increase your knowledge of the duties and skills of other men in the construction group. The training courses prepared for Utilitiesman, and Steelworker are likely to be of particular interest to you.

OFFICER TEXTS.—Officer texts that you may find helpful when you are preparing for advancement to CE1 and CEC include Maintenance of Public Works Utilities, NavDocks MO-100 series and MO-306 as applicable; Refuse Disposal, NavDocks MO-213; Insect and Rodent Control, NavDocks TP-PU2; and Snow Removal, NavDocks TP-PW-29; Power Generation and Distribution, NavDocks TP-PU-3 with chapters 1, 4, 6, 7, 8, and 9, superseded by DM3 and DM4 where applicable; Public Works Department Management, NavPers 10893-A; Uniform Code of Military Justice, Addendum to the Manual for Courts-Martial (1963).

CORRESPONDENCE COURSES.—Most Navy Training Courses and Officer Texts are used as the basis for correspondence courses. Completion of a mandatory training course can be accomplished by passing the correspondence course that is based on the training course. You will find it helpful to take other correspondence courses, as well as those that are based on mandatory training courses. For example, the completion of the correspondence course based on Maintenance of Public Works and Public Utilities is strongly recommended for personnel preparing for advancement to CEC. Taking a correspondence course helps you to master the information given in the training course or text and also gives you a pretty good idea of how much you have learned from studying the book.

OTHER BUPERS PUBLICATIONS.—Additional BuPers publications that you may find useful in connection with your responsibilities for leadership, supervision, and training include the Manual for Navy Instructors, NavPers 16103-C, and the Naval Training Bulletin, NavPers 14900 (published quarterly).

GOVERNMENT PUBLICATIONS

Many of the reference materials helpful for the CE rating are issued by the United States Government. Your training officer should be able to obtain these materials for use at your activity. If you desire a personal copy of a Government publication, write to the Superintendent of Documents, Government Printing Office, Washington, D.C. 20390 and inquire whether the publication you desire is for sale; many, in fact, are available through this source.

BuDocks Publications

The Bureau of Yards and Docks issues a number of publications that are of benefit to Construction Electricians. Electrical Power Generation, chapter 1, TP-Pu-3; Mobile Emergency Power Plants, chapter 2, TP-Pu-3; Electric Power Distribution, chapter 8, TP-Pu-3; Advance Base Electrical and Communication Systems, TP-PL-15; and Wire Communications and Signal Systems, chapter 1, TP-Pe-5, for example, contain a great deal of information on power generators, power distribution, emergency power plant and communications systems. Although these publications are intended for practical use in the field, they also make useful reference books for self-study or instruction.

Mobile Construction Battalion Administration, NavDocks P-315, is a guide for the organization and administration of MCBs. This publication describes battalion organization operations, training, safety, and similar matters. NavDocks P-315 is a useful publication for MCB officers and petty officers.

The Navy Civil Engineer, NavDocks P-330, is a monthly magazine issued by BuDocks. This magazine is sent to all Civil Engineer Corps officers, so there should be several copies in your battalion. The Navy Civil Engineer is intended to keep CEC officers and other interested personnel abreast of developments in the Shore Establishment with respect to planning, design, construction, and maintenance. Most articles discuss Seabee operations or technical developments.

Army Technical Manuals

The Army has issued a series of technical manuals (TMs) on many topics of interest to Construction Electricians. The TM 5- series contains information on electrical power equipment, distribution, maintenance, and installation. The TM 9- series contains information on electrical communications equipment. You will find many of the publications in the 5 and 9 series very helpful.

The titles of all TMs are listed in the Index of Technical Manuals, Department of the Army Pamphlet No. 310-4.

Landing Party Manual

The Landing Party Manual, OpNav P 34-03, is the Navy's guide for organizing landing parties from units afloat and emergency ground defense force units. It contains chapters on such matters as military drill ceremonies, interior guard duty, special operations, combat techniques, and combat principles among others. The chapters on combat are particularly important to men in the Seabee ratings, since Seabees are responsible for defending their own areas.

MANUFACTURERS' MANUALS

When new equipment is procured by the Navy, this equipment almost always is accompanied by a manual of operating, maintenance, and installation instructions. These manuals should be kept readily available for reference. They describe in detail the procedures for installing, operating and maintaining a specific piece of equipment.

Study the manuals for each piece of equipment for which you are responsible; make certain that you understand the manual thoroughly. It will be the men assigned to you, of course—not you—who will actually install and maintain the equipment. Your responsibility is to make certain that the men understand their equipment and that they know how to follow the instructions in the manufacturer's manual or manuals for a specific piece of equipment. To carry out your responsibility in this respect, you must become thoroughly familiar with both the equipment and the accompanying manuals.

COMMERCIAL PUBLICATIONS

There are many commercial publications of use to Construction Electricians. Numerous

texts have been published dealing with the fundamentals of electricity to the complex engineering phases. You will profit by studying some of these texts to increase your knowledge; you may also find some of these texts helpful as instruction manuals for your men.

No attempt will be made here to list all commercial publications that may be useful; only two will be mentioned. The officers in your battalion may be able to recommend others; some commercial texts may be available in your battalion.

The Lineman's Handbook by Edwin B. Kurtz, published by McGraw-Hill Book Company Inc. of New York, New York, is an excellent handbook for all phases of power distribution, construction and maintenance procedures. It makes an excellent home-study book for those in the CEP rating.

National Electrical Code, by National Board of Fire Underwriters, New York, New York, is an excellent guide for proper and safe procedures in installing electrical devices.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. A selected list of training films that may be useful to you is given in appendix 1 of this training course. Other films that may be of interest are listed in the U.S. Navy Film Catalog, NavWep 10-1-777.

ORDERING PUBLICATIONS

All training manuals listed in the latest NavPers 10061 may be obtained from Forms and Publications Supply (FPS) distribution points in accordance with instructions set forth in NavSandA publication 2002, Requisitioning Guide and Index of Forms and Publications. Cognizance Symbol "I", DD Form 1348, should be used and filled out as directed in NavSandA publication 2002. All new and revised Navy Training Courses are being given an automatic initial distribution. Department of Defense and other Government publications ordering procedures are also covered in NavSandA publication 2002.

ADVANCEMENT OPPORTUNITIES FOR PETTY OFFICERS

Making chief is not the end of the line as far as advancement is concerned. Proficiency pay, advancement to E-8 and E-9, and advancement to commissioned officer status are among the opportunities that are available to qualified petty officers. These special paths of advancement are open to personnel who have demonstrated outstanding professional ability, the highest order of leadership and military responsibility, and unquestionable moral integrity.

PROFICIENCY PAY

The Career Compensation Act of 1949, as amended, provides for the award of proficiency pay to designated enlisted personnel who possess special proficiency in a military skill. Proficiency pay is given in addition to your regular pay and allowances and any special or incentive pay to which you are entitled. Enlisted personnel in pay grades E-4 through E-9 are eligible for proficiency pay. Proficiency pay is allocated by ratings, with most awards being given in the ratings which are designated as critical. The eligibility requirements for proficiency pay are subject to change. In general, however, you must be recommended by your commanding officer, have a certain length of time on continuous active duty, and get a sufficiently high mark on a Navy-wide proficiency examination in the subject matter of your own rating.

ADVANCEMENT TO E-8 AND E-9

Chief petty officers may qualify for the advanced grades E-8 and E-9 which are now provided in the enlisted pay structure. These advanced grades provide for substantial increases in pay, together with increased responsibilities and additional prestige. The requirements for advancement to E-8 and E-9 are subject to change, but in general include a certain length of time in grade, a certain length of time in the naval service, a recommendation by the commanding officer, and a sufficiently high mark on the servicewide examination. The final selection for E-8 and E-9 is made by a regularly convened selection board.

Examination Subjects.—The examinations for pay grades E-8 and E-9 are divided into three sections: professional knowledge, supervisory knowledge, and common knowledge. The professional knowledge section is designed to measure, at an advanced level, a candidate's knowledge of his particular rating. The officers who prepare these questions are guided

by the Manual of Qualifications for Advancement in Rating and the related bibliography in Training Publications for Advancement in Rating. Pertinent publications from among those listed in the military requirements section of NavPers 10052 are used as sources of the supervisory knowledge section. The common knowledge section contains questions designed to test the candidate's arithmetical, mechanical, and verbal reasoning capabilities. Questions for this section are drawn from basic mathematics, physics, and vocabulary development texts.

Sources of Advancement Information.—In addition to the titles listed above, the following publications, distributed to Navy libraries and Educational Services offices, will assist the candidate for E-8 or E-9 in preparing for the examinations: College Entrance Examinations Study Material (limited distribution); High School Subjects Self Taught Book (Navy-wide distribution); Basic Mathematics (Navy-wide distribution); Mathematics Review (Navy-wide distribution); popular texts on psychology (Navy-wide distribution); various USAFI texts (Navy-wide distribution); vocabulary development books (limited distribution).

ADVANCEMENT TO COMMISSIONED OFFICER

The Navy's promotion ladder offers a pathway to a commission for qualified active duty personnel E6 and above. One path leading to the commissioned ranks is through the warrant officer to LDO civil engineer.

There are several programs that enlisted personnel may select from to gain a commission if they are eligible. Because of the changing qualifications that are made to meet the needs of the Navy, they will not all be covered here. If you are interested in advancing to a commission, ask your educational service officer for the latest requirements that apply to your particular case.

The paths that are open to enlisted personnel are: the integration program; the warrant officer program (which most CEs will be interested in); the medical service corps program; and the NESEP program. Eligibility requirements for these programs vary according to circumstances and are subject to change.

CHAPTER 2

DEFENSIVE TACTICS

As a third class petty officer you were qualified to lead a fire team, the smallest of combat units. As a second class petty officer you were qualified to lead a squad, containing three fire teams. As a first class or chief petty officer you will be performing duties of platoon guide, platoon chief, platoon commander, or in some cases, company chief.

As the platoon chief, or platoon commander, you will be responsible for the safety, training, welfare, efficiency, and morale of the entire platoon. As platoon guide you will be responsible for the platoon's supplies, as well as for assisting the platoon chief and platoon commander in the performance of their duties. As platoon chief or platoon guide you must be able to perform the duties of all those subordinate to you, and those of your immediate superior in the platoon.

As a company chief or platoon commander you now must know the duties and responsibilities of a company commander so that you may properly assist him in company operations or take charge in his absence.

This chapter will acquaint you with certain combat principles, tactics, and techniques with which you must be familiar in order to carry out your duties and responsibilities in the various positions mentioned above. Of course, it must be realized that some military duties are not strictly combat in nature, but nevertheless are an important part of the overall duties of a first class or chief petty officer. Some of these duties will be presented, when they apply, throughout this chapter.

BATTALION ORGANIZATION

You should be familiar with the latest basic battalion defense organization. The latest (September 1964) changes to the battalion organization are reflected in figure 2-1. Now would be a good time to review the defensive tactics section of the latest CN and Group VIII 3 & 2 training publications courses since they reflect the latest word in defensive tactics for those levels.

As you can see in figure 2-1, CHARLIE and DELTA companies are the two general construction companies. They may "subcontract" portions of their construction projects to ALFA and BRAVO companies on normal deployments, but in a contingency operation CHARLIE and DELTA companies are augmented by the platoons and/or squads of ALFA and BRAVO companies, supported by Headquarters company, and become self-sufficient in both construction and defense. Whenever CHARLIE or DELTA company physically separate, one-half of Headquarters company may be assigned to CHARLIE company and one-half may be assigned to DELTA company. Thus, in effect, we have two complete half MCBs. It is, therefore, very important to keep the units in ALFA, BRAVO, and Headquarters companies divisible by two in order to maintain an equal balance of the capabilities of CHARLIE and DELTA companies in a contingency operation.

COMPANY ORGANIZATION

The CB rifle company is organized to ensure effective control, flexibility of employment, and rapid reorganization, and has triangular organization down through the fire team. It is built around three rifle platoons, supported by a weapons platoon, and controlled and coordinated by a company headquarters.

PLATOON ORGANIZATION

As you know, the rifle platoon is the basic defensive unit of the rifle company and has the same general mission as all infantry units. The

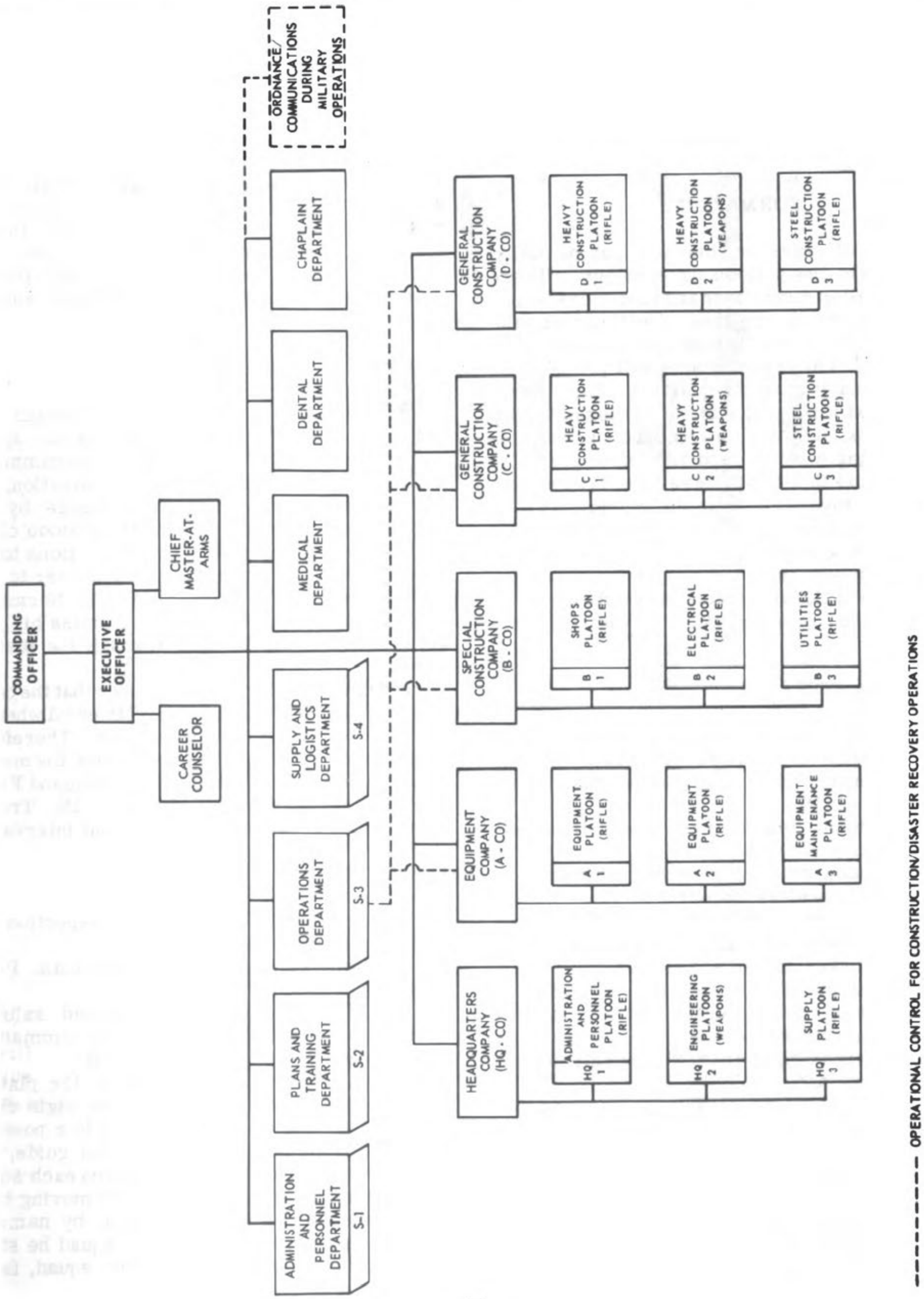

Figure 2-1. —Standard mobile construction battalion organization.

platoon is organized around a platoon headquarters for coordination and control and contains three rifle squads to provide a balanced fire and maneuver team. The rifle squad is further broken down into three fire teams, again to provide for effective control and a balanced team (see fig. 2-2).

FORMATIONS

As a first class or chief you may be called upon to form the platoon or company. There are many troop formations and variations thereof. For practical purposes we will discuss the formations and procedures more commonly used by an MCB. These formations will probably be the ones used at morning quarters. Formations may be used for a multitude of purposes. They offer a quick, easy way, to account for personnel, for inspecting weapons, and issuing of gear.

You'll find that it will save time to assemble the men in formation in an emergency, as they will be doing something familiar, therefore are less likely to get confused, and it will be easier to make assignments because of the organization. For additional information on formations, refer to the Landing Party Manual, OpNav P34-03.

FORMING A COMPANY

To form a company in the formation illustrated in Figure 2-3, the procedure is as follows:

1. Company chief assemes position, commands: FALL IN.
2. Platoons fall in three paces front and center of the platoon chief.
3. Platoon chief commands: REPORT.
4. Squad leaders report (saluting and accounting for each individual).
5. Platoon chief salutes (this acknowledges report; he makes no verbal response).
6. Company chief commands: REPORT.
7. Platoon chief salutes and reports (all present or accounted for).
8. Company chief acknowledges all reports and then commands: POST.
9. Platoon chiefs assume position as last man of third squad by moving by most direct route.
10. Company commander commands: REPORT.
11. Company chief salutes and reports.
12. Company commander acknowledges report and commands: TAKE YOUR POST.
13. Company chief assumes his position behind third squad leader of center platoon, moving by most direct route.
14. As the company chief steps off to move to his posted position, the platoon commander moves by the most direct route to a position 6 paces front and center of the platoon. NOTE: There is no specific position, left or right, from where the platoon commander moves to his position 6 paces in front of his platoon. But, to make the movement military, all platoon commanders should move simultaneously from a predetermined position in accordance with the situation.

FORMING A PLATOON

In forming a platoon, steps 1 through 5 as indicated above for forming a company apply, except that the platoon chief gives the command: FALL IN. Depending upon the situation, the platoon commander may take charge by receiving the report and posting the platoon chief. Or, he may issue orders or instructions to the platoon chief and turn the platoon over to him with the command: TAKE CHARGE. Normally, a platoon commander does not dismiss his platoon directly, but does so through the platoon chief.

In forming a platoon, remember that the command, FALL IN, means normal interval whether the platoon is under arms or not. Therefore, when space is limited and you desire the men to be at close interval, qualify the command FALL IN with: at close interval, FALL IN. Troops under arms always fall in at normal interval.

INSPECTION

In preparing a company for inspection the following procedures apply:

1. Company commander commands: PREPARE FOR INSPECTION.
2. Platoon commander without saluting does an about face and first platoon commander commands: OPEN RANKS, MARCH.
3. On the command MARCH the platoon commander of the platoon on the right flank steps off by the most direct route to a position 1 pace to the right of the platoon guide, and faces down the ranks. He then aligns each squad by doing steps left or right without moving head or hands, aligning each individual by name or number. After aligning the first squad he steps off as in marching to the second squad, faces

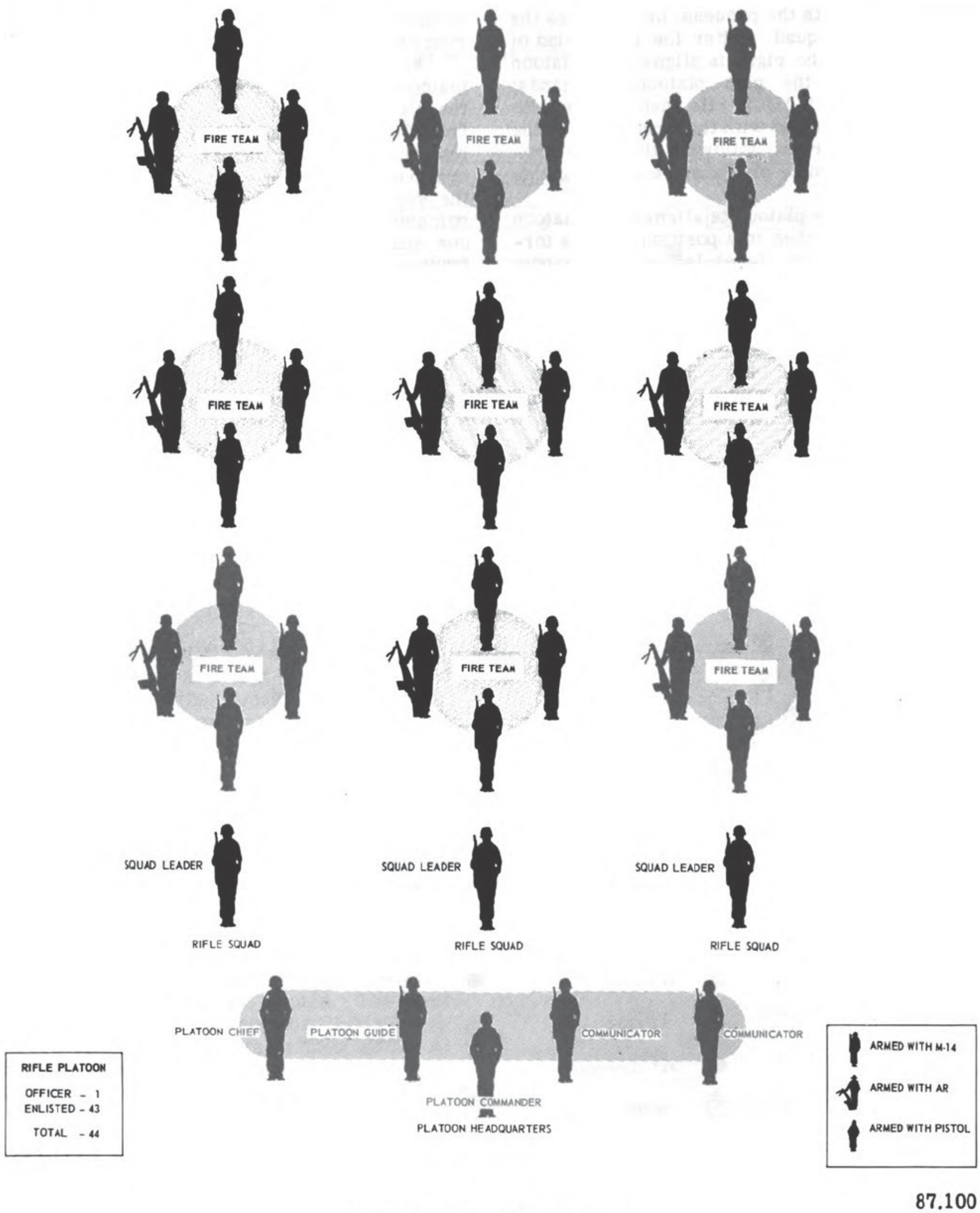

Figure 2-2.—Rifle platoon.

right and repeats the process; he then does the same to third squad. After the first squad of the platoon on the right is aligned, the platoon commander of the next platoon commands: OPEN RANKS, MARCH. He then proceeds to align his first squad with the first squad of the platoon on his right, following the same procedures. Remaining platoons are aligned in this same manner.

4. When the platoon is aligned, the platoon commander marches to a position 3 paces forward of the platoon, faces left and commands: READY, FRONT; he then takes 1 pace forward and faces front to await the inspecting officer. The company is now formed as illustrated in Figure 2-4.

5. When all the platoons are aligned in this manner the company commander will then command: AT EASE.

6. The company commander will then proceed by the most direct route to the platoon on the right flank.

7. The platoon commander will call his platoon to attention, salute and report to the company commander. He will say how many men he has present.

8. The company commander inspects the platoon commander first. He then steps around the platoon commander's left, to a position in front of the first man in the front rank. After the platoon commander is passed by the company commander, he proceeds to a position in front of the second man in the front rank. The platoon commander precedes the company commander by one man during the entire inspection down the front and rear of each squad. With permission of the company commander, the platoon commander may place squads not being inspected at ease.

9. When the platoon has been inspected the platoon commander does a column left, marches 3 paces beyond front rank, faces platoon, and calls them to attention; he then takes 1 step forward and faces front.

10. The company commander follows the platoon commander, passing by his right side to a position about 3 paces forward of the platoon commander, faces about, and makes any remarks or comments he might have; they

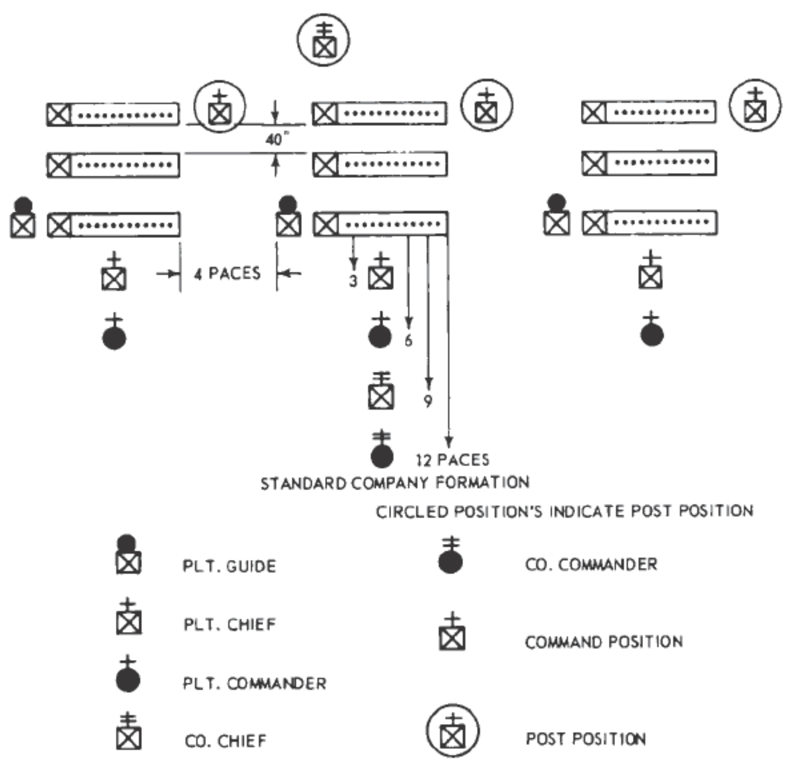

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Figure 2-3.—Standard company formation.

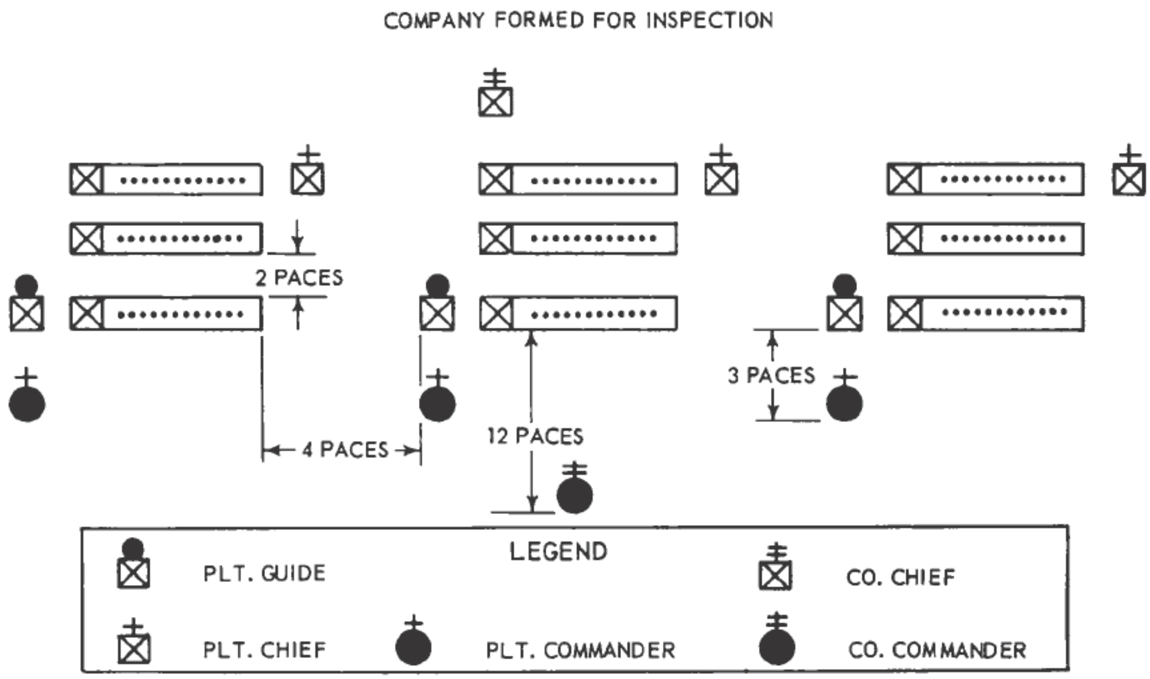

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Figure 2-4.—Company formed for inspection.

exchange salutes and the company commander proceeds by the most direct route to the next platoon and repeats the process.

11. The platoon commander faces left and commands CLOSE RANKS, MARCH; he then resumes his position 6 paces front and center of his platoon and gives the command REST, or AT EASE.

12. When the company commander has completed his inspection he returns to his position 12 paces front and center of the company and commands, COMPANY CHIEF, FRONT AND CENTER. The company chief moves by the most direct route to his position 9 paces front and center of the company, faces the company commander and they exchange salutes. The company commander then commands DISMISS THE COMPANY. They exchange salutes again. At this time the company commander and the platoon commanders fall out.

13. As the platoon commanders fall out, the platoon chiefs resume their positions 3 paces front and center of their platoon. When the platoon chiefs are all in position the company chief commands FALL OUT or PLATOON CHIEFS, DISMISS YOUR PLATOONS.

As you can see in figure 2-3, the triangular organization (based on units of 3) is also used in position distances and areas of direct responsibility. The platoon chiefs position is 3 paces in front of the first squads position. The platoon commander's position is 3 paces in front of the platoon chief's position, the company chief's position is 3 paces forward of the platoon commander's position, and the company commander's position is 3 paces forward of the company chief's position. Each person in charge is usually only directly in charge of three men: fire team leader - 3 men, squad leader - 3 fire team leaders, platoon commander - 3 squad leaders.

TROOP MOVEMENTS

Troop movements may be classed as tactical or administrative.

Tactical troop movements are made under combat conditions. Security measures are therefore a vital consideration. When a tactical move is made, the overriding consideration is normally the requirements of the tactical situation rather than the efficient use of transportation facilities.

Administrative troop movements are made when ground contact with the enemy is not a consideration and when there is no need for special security requirements other than secrecy and those necessitated by enemy long-range aircraft and missiles.

A successful movement places troops at their destination at the proper time and in condition to defend themselves while completing their mission. The fundamentals of preliminary steps and planning of convoys are common to all types of movements. Only in the execution do different techniques appear.

Rapid, secret, and efficient concentration of troops is one element essential to a successful battle plan. Successful troop movements are characterized by the following:

Plans which are within the capabilities of the troops, and methods of execution which will put them at their destination in the best possible condition to accomplish their mission.

Strict adherence to prescribed schedules and routes. Critical points must be reached at the time specified or confusion and interference with other elements may result.

Maintenance of control, command unity, and combat effectiveness of the troops throughout the movement.

In the Seabees you will have occasion to move by all modes of transportation, from tractor trains to jet aircraft, and of course on foot. All troop movements have many things in common. Troops are always organized into unit sizes that are manageable for the mode of movement. The movement order for all modes of movement contains about the same information, the checking of personnel and the checking of baggage not carried by the man are also the same.

When a Seabee battalion moves to carry out an assigned mission it must take its equipment with it, whether the equipment precedes the troops, travels on the same carrier, or follows them.

With the present organic allowance an MCB cannot move all its equipment and personnel by vehicle in one loading; therefore additional equipment must be requested or additional trips must be made with the organic equipment.

When the decision to move has been made, a brief WARNING ORDER is issued to allow subordinate elements time for preparation. A WARNING ORDER answers as many of the following questions as possible:

Who? (The unit or units involved.)

What? (The nature of the movements.)

When? (The time the movement is to begin.)

Where? (The destination.)

Why? (The general purpose of the operation.)

The MOVEMENT ORDER includes the following information:

Object and destination of the movement.

Distribution of troops and order of march of the main body.

Special security measures.

Initial or starting point (usually on the route of movement).

Hour the head of the leading unit clears the initial point.

Any other information necessary for complete understanding by subordinate commanders.

Ordinarily, a motor march column is formed by the arrival of component units at an initial point according to their prescribed order of march in the column.

START OF THE MOTOR MARCH

Canteens should be filled the night before the march. Men who have been classified sick or physically unfit at morning sick call will not be required to march. When men fall in, there should be no delay in starting; standing around is especially fatiguing. The sanitary officer and a police detail remain a few minutes after the camp is cleared to see that the camp site is left in a clean and sanitary condition.

LENGTH AND RATE OF MARCH

The distance covered by a motor march in a day is governed by the slowest moving unit in the convoy. This will usually be a heavily loaded lowboy or a self-propelled piece of construction equipment. If it is necessary for a portion of the troops to march on foot, they should start out ahead of the equipment. When the troop carriers deliver the vehicle mounted troops, they return and pick up the foot column wherever they are along the route of march.

The interval between vehicles and units is determined by the speed of the column over that section of the route, keeping in mind that the slowest vehicle sets the pace. In order to reduce traffic congestion, it is often wise to separate the column into units that have vehicles with the same approximate travel speed, and have them travel independent of each other.

It is desirable to arrive at the end of the march as early in the day as practicable so that camp may be made during daylight, thus providing maximum rest for the troops; accordingly, long halts during the day are not made unless required by special conditions.

HALTS

Halts are made for purposes of rest, personal comfort and relief, messing, refueling, maintenance and inspection of equipment, and allowing other traffic to pass.

The time and duration of halts as well as their purpose are usually prescribed in orders from higher headquarters. A halt of 15 minutes is normally made at the end of the first hour, with a 10-minute halt every 2 hours thereafter. One-half hour to one hour is generally allowed for mess and refueling halts. When it is necessary to allow others to pass and the situation permits, mess and refueling halts should be scheduled to coincide, thus utilizing necessary delay to advantage. To maintain proper gaps between serials it is necessary that all elements halt at the same time. In cases of radio silence or where intracolumn communication is inadequate, the time of each halt may be scheduled in orders.

Location

The locations for scheduled halts should be selected in advance, specifically ordered, and plotted on road movement graphs. These selections may be prescribed by higher authority, made tentatively by map reference, or made by the reconnaissance party. On dispatch routes, highway regulation points may include refueling stations, messing facilities, temporary quarters, and maintenance facilities. When such facilities have been provided, highway regulation orders or other orders from higher headquarters usually prescribe the places at which halts will be made.

If the unit is of brief duration and will not interfere with normal traffic flow, the column may stop on the shoulder of the road. It is desirable that halting places, especially off-road areas, provide turnaround facilities or circuitous exits so that the column may be quickly reversed or be able to re-enter the route when necessary.

If crossroads, railroad crossings, or similar danger points lie within the halt area of a column, subordinate commanders will require vehicles to stop a reasonable safe distance from such points; no part of a column should stop on bridges. Halts on steep grades and sharp curves should be avoided.

Comfort of personnel and servicing facilities for vehicles are important considerations in selecting sites for long halts. If a column starts from a populous area, its first halt should be delayed, when practicable, until a rural area is reached to facilitate relief of personnel. For the same reason halts should not ordinarily be made in villages or towns unless there is a special need.

Precautions at Halts

Columns should be halted at points providing a clear view; normally more than 200 yards should be maintained to the front and to the rear of the column. If road conditions prevent adequate sight distances, steps must be taken to forewarn approaching traffic.

Guards, warning flags, caution lights, or flares (security conditions permitting) should be posted in front and rear of the column and at any other points where there is a hazard to passing traffic. If the column blocks part of the road at the halt so that it is necessary to operate one-way traffic, authorized traffic movements may be alternated by using flags transmitted from one end of the single lane to the other by the last vehicle of each passing group or by guards controlling traffic by signal.

When the column halts on the traveled way forcing traffic moving in the same direction to cross the centerline, vehicles may be parked with enough distance between to allow passing vehicles to enter the column upon the approach of vehicles from the opposite direction.

Unless otherwise prescribed, when traffic approaches from the rear of the halted column and cannot clear the column before its resumption of movement, officers may require such traffic to remain behind until it is safe to pass.

All personnel other than traffic guides must remain off the road to the right of their assigned vehicles, keeping the traveled portion of the road clear at all times. Men are not permitted to leave their unit's immediate vicinity during halts without specific authority from an officer of their unit.

Duties at Halts

Officers and petty officers will check the welfare of personnel, the security of loads, and the performance of first echelon maintenance. Control personnel will make necessary inspections and give instructions to insure prompt resumption of the movement with a minimum of confusion at the end of the halt. Mess, medical, and maintenance personnel will perform such special duties as the purpose and duration of the halt permit.

When the column is halted for any reason other than the hourly halt, the commander halts the leading element. Troops are informed of the length of each halt so that they can take full advantage of it.

MARCH DISCIPLINE

March discipline is attained through training and through internal control within the marching unit. It is indispensable to the effectiveness of the march column. The specific objective of march discipline is to insure intelligent cooperation and effective teamwork on the part of all march personnel. Such cooperation and teamwork can be attained only by thorough training, constant supervision by every officer and petty officer, practical experience in marching, and meticulous attention to details of technique listed below.

1. Correct driving.
2. Immediate and effective response to all signals and orders.
3. Prompt relaying of visual signals.
4. Strict obedience to traffic regulations, rules of the road, and instructions of highway regulating, traffic control, and command personnel.
5. Effective use, as prescribed, of cover, concealment, camouflage, dispersion, radio silence, blackout precautions, and other protective measures against air, ground, or NBC attack.
6. Correct speeds, distances, and positions within the column.
7. Observance of the rules of march hygiene.
8. Proper care of equipment.

The responsibility for good march discipline begins with the driver of each vehicle and increases with each commander charged with internal control. Their duties are briefly as follows:

1. The driver of each vehicle is responsible for observing the proper distance and speed, for safety precautions, for good driving, for performance of prescribed first echelon maintenance, and for strict observance of all requirements of standing operating procedure or specific orders governing the march. The driver will be given adequate orientation on routing and destination to insure safe arrival in the event of separation from the column. When time and facilities permit, he should be supplied with a strip map of his route.
2. The assistant driver should be constantly on the alert for column signals and warnings and for signs placed along the road, warning the driver and transmitting such information back along the column when appropriate. This is particularly important at night or under conditions of poor visibility. He should assist the driver in every way possible; guarding against his falling asleep, assisting in at-halt maintenance service, and helping with emergency repairs.
3. Squad leaders supervise the actions of the drivers of the vehicles composing their squads, giving particular attention to spacing of vehicles and the performance of first echelon maintenance.
4. Section leaders and/or platoon leaders supervise the actions of the squad leaders, giving them such instructions as may be required for the proper functioning of their sections or platoons.
5. The march unit leader or commander gives the orders to move or halt and exercises general supervision over the conduct of his unit. He is responsible for maintaining the proper position of his march unit within a larger column and for carrying out the orders of the column commander.
6. Commanders in a convoy, column, or serial are responsible for their units, the responsibility becoming broader and more general in nature at each higher level of command.

MEALS

Field rations may be issued prior to the march for consumption en route. If at all possible, a hot meal should be served after the end of the day's march.

To replace the fluids lost by evaporation, a definite quantity of water must be consumed by each individual.

FORCED MARCHES

Forced marches seriously impair the fighting power of even the best troops and are undertaken only in cases of urgent necessity.

With foot troops, forced marches are generally made by increasing the number of marching hours; halts and periods for cooking and sleep being arranged to afford maximum benefit. The rules prescribed for average marches are followed as closely as possible.

MARCH SECURITY

ADVANCE GUARDS

An advance guard is a security detachment that precedes and protects the main body of a force moving toward the enemy, whatever its formation, and covers its deployment for action when contact is made.

If a force moves in more than one column, each is covered by its own advance guard. Elements not covered by the advance guard in their development for action likewise provide their own security detachments.

This section describes the security measures considered necessary for the protection of a column or columns moving into hostile territory under conditions where contact with the enemy is possible.

Tasks and Duties

The principal tasks of advance guards are:

To ensure the uninterrupted advance of the main body.

To protect it against surprise and observation by hostile ground forces.

To cover the deployment of the main body when the enemy is encountered in such strength as to require the employment of the whole force.

In accomplishing its mission, advance guards are required to:

Remove obstacles and repair roads and bridges.

Reconnoiter to the front and flanks to secure information.

Drive back small bodies of the enemy, to prevent their observing, firing upon, or delaying the main body.

Secure terrain features which protect the main body from hostile fire and observation, and which provide suitable positions for observing the fire of friendly supporting weapons.

Seize suitable commanding positions to cover the deployment of the main body when movement is definitely stopped, and determine the strength, disposition, and flanks of enemy forces.

Distribution of Troops

An advance guard is generally subdivided from front to rear as follows:

1. Point (sent out by the advance party)
2. Advance party (sent out by the support)
3. Support (sent out by the reserve)
4. Reserve

Patrols are sent out to the flanks by the advance party and the support proper. Additional patrols are employed when necessary.

Contact between the elements of an advance guard is maintained from rear to front by connecting files or groups.

Strength and Composition

The larger the command, the larger in proportion is the advance guard, because a large command takes relatively longer to prepare for action than a small one.

Units functioning as advance guards should have sufficient supporting weapons.

Table 2-1 will serve as a guide for the maximum size of advance guards and their elements for various organizations.

Formation and Distances

In order to give the elements of an advance guard and the main body time and space to carry out their missions it is necessary for them to advance with distances between them. These distances are in addition to the road spaces occupied by each element. None of these distances are set. They vary with the mission of the whole command, the size of the elements, the terrain, the proximity to and nature of the enemy, and visibility such as daylight, darkness, or fog. Distances should be less in rolling terrain where successive positions afford protection than in open, flat terrain. They should be less at night than in the day. They should be less when pursuing a beaten enemy than when approaching an unbeaten one.

The Point

The point is a patrol sent forward by the advance party to give rear elements warning

Table 2-1. —Composition of Advance Guards.

Main body	Advance guard, total	Subdivision of advance guard			
		Reserve	Support	Advance party	Point
Battalion (less 1 company).....	1 company	None.....	1 rifle company (less advance party).	1 platoon plus 1 section machine guns (less point).	1 squad.
Company (less 1 platoon)....	1 platoon plus 1 section machine guns.	...do....	None..........	...do..........	Do.
Platoon (less 1 squad)	1 squad	...do....	...do........	None...........	Do.

of the presence of hostile forces. It reconnoiters to the front and immediate flanks and sends to the rear all information obtained.

The point confines its activities to the axis of march and drives back all small hostile parties encountered. When large hostile bodies are observed, it pushes on until forced to halt by fire; when troops in rear are halted by fire, it covers their deployment or, if such protection is unnecessary, acting as a patrol, it makes every effort to locate the enemy flanks and to determine the amount of the resistance. Different action may be required depending upon the mission of the command as a whole; e.g., should reconnaissance be paramount the point would be ordered to halt, conceal itself, observe, and send back information whenever hostile activities are encountered.

The point usually regulates its march on the advance party, one member being detailed to observe to the rear, to maintain distance, and to receive signals.

The Advance Party

The advance party is sent forward by, and constitutes the reconnoitering element of, the support. It is made strong enough to guard the support against surprise by effective hostile rifle fire. To accomplish this it:

Provides the point.

Supports the action of the point.

Furnishes patrols for reconnaissance and security to the flanks.

The advance party drives back enemy patrols and takes care of minor resistance which the point is unable to overcome. It checks an enemy attack sufficiently to cover the deployment of the support.

The advance party commander is usually responsible for the route of march and for the regulation of the rate of march for the entire column.

The Support

The support provides for its own security by sending an advance party forward and patrols to its flanks.

The support reinforces the action of its advance party in dealing with minor resistance, or when the enemy is encountered in force it offers sufficient resistance to permit the reserve to prepare for action in accordance with a definite plan.

The support commander gives definite instructions as to what patrolling will be done by the advance party, and orders such patrolling by the support as cannot be accomplished by the advance party. He stations himself where he can quickly see and estimate the situation when his unit is fired upon; usually this position is with the advance party or between it and the support.

Connecting Elements

Visual contact between elements of a column is maintained by two or more units placed in

the space between the elements. The units so designated are referred to as connecting groups. Contact is usually maintained from rear to front. Therefore, whatever measures that may be required are furnished by the element in rear to maintain contact with the element next in front. They are so spaced that each group can maintain constant visual contact with both the following and preceding file, group, or unit. When visibility is good, two connecting groups may be sufficient; in darkness or on roads with poor visibility a larger number of groups are needed.

Connecting groups halt on orders or signals from the rear, or when the point halts, relaying the signal to the front or rear.

Members of connecting groups look alternately to the rear and to the front for signals and move, or halt as is necessary to maintain contact both to the front and rear.

REAR GUARDS

A retiring force covers its retirement by a rear guard. A force moving toward the enemy details a rear guard, if attack or harassing action to its rear is possible. The size of such rear guards depends upon enemy capabilities.

The rear guard protects the main body from surprise, harassment, attack, or observation from the rear by hostile ground forces. Its mission and employment is similar to that of the advance guard, except that it is concerned with observation and action to the rear of the column.

FLANK GUARDS

The flank guard protects a moving command from enemy ground observation and surprise action on the flank and, in the event of an attack in force, provides the necessary time and space for the deployment of the main body.

Flank guards may be employed in three ways:

1. OCCUPYING A SINGLE FLANK POSITION. If there is only a single avenue of hostile approach from a threatened flank, the flank guard occupies a position which covers that route. It remains in that position until the column has passed, at which time it joins the rear of the column.

2. OCCUPYING A SERIES OF FLANK POSITIONS. When several dangerous localities must be passed during the march, the flank guard may occupy several of these positions simultaneously, moving forward in "leap frog" fashion. As the tail of the column passes one danger spot, the element of the flank guard occupying that position may be advanced to the next unoccupied position to be blocked. This simultaneous occupation of a series of flank positions continues as long as the terrain and the situation demand. The flank guard reassembles after the tail of the main body has passed a prescribed location, or at a specified time. It rejoins the main body as soon as practicable.

3, MOVING PARALLEL TO THE MAIN BODY. When a route exists generally parallel to the line of march, and flank protection is required, the flank guard may march parallel to the main body. It may also be distributed in small detachments, over sufficient depth to the flank to resist an attack at various points along the flank of the main body. Depending on the terrain and situation, the employment of an additional unit in conjunction with flank guards may be advisable.

THE BIVOUAC SITE

Prior to the arrival of the troops, a quartering party selects the bivouac site. This party usually consists of the officer in charge, two supply representatives, a medical representative, and a representative of each unit to be on the bivouac.

The selection of the bivouac site is governed by both military and sanitary considerations; however, tactical requirements always have priority over other considerations. If the bivouac site has been previously designated by higher authority, a quartering party will precede the troops and prepare to establish the area for bivouac.

Tactical requirements to be considered are:

Sufficient space for proper dispersal of the command.

Concealment from air and ground observation.

Protection against bombing or strafing attack.

Protection against mechanized attack.

Desirable features for sanitation of the area and comfort of the troops are as follows:

Ample supply of water for drinking, bathing, and washing clothes.

Grass covered area of sandy, loam, or gravel soil.

Elevated site, well drained, but not a steep slope.

Shade trees in warm weather; hills as windbreaks in cold weather.

Accessibility to good roads.

Location removed from marshes, swamps, mosquito breeding areas, native habitations, or any other unsanitary areas.

A site not occupied by other units within the preceding 2 months.

When the bivouac site has been selected, the following provisions should be made.

PRIOR TO THE ARRIVAL OF THE TROOPS:

Select definite areas within the bivouac site for each unit (platoon or company).

Make a reconnaissance to determine the number of outguards necessary for security of the bivouac.

Mark unit areas and post necessary guides.

Select galley sites near the road for ease of supply, but far enough from the road that dust will not hinder cleanliness, as near the water supply as possible, and with adequate drainage.

Establish the head on the opposite side of the bivouac and downgrade from the galley.

AFTER THE ARRIVAL OF THE TROOPS:

Establish the necessary outposts, outguards, and patrols.

Establish interior guard. Guardposts should be established immediately at the commissary dump, at the water supply and in the unit areas. This is necessary in order to see that the water supply is correctly used, that food is not damaged or stolen, and that sanitary discipline is maintained.

Details are assigned to:

Dig the heads.

Set up the galley.

Dig the kitchen pits (one for dry garbage and trash that can be burned, and one for wet garbage which must be covered daily).

Set up the sick bay and headquarters tents.

Procure fuel, water, etc.

Troops not assigned to the above details will pitch tents and trench them immediately.

The above assignments should be made prior to arrival of troops. This will prevent delay and confusion once the site has been reached. See figure 2-5 for a sample bivouac site.

OUTPOSTS

An outpost is a security detachment distributed at some distance from the main body of troops, while at a halt, in camp or bivouac, or in battle position. Its purpose is to protect friendly forces from observation and surprise by the enemy.

Enemy capabilities, terrain, and the location of the main body determine the location and nature of the outpost.

The strength and composition of an outpost vary with the distance, mobility, armament, and attitude of the enemy; the terrain; the time of day; the size of command to be secured; the degree of resistance desired; and the special tasks assigned.

The primary mission of an outpost is security. This mission is accomplished by:

1. Reconnaissance.
2. Observing and reporting information relating to the activity of the enemy.
3. Preventing the enemy from gaining information.
4. Giving warning of a hostile attack.
5. Deceiving the enemy as to the location of the main body or the battle position.
6. Developing enemy dispositions and delaying the hostile attack to allow the commander of the force to prepare for combat.

There are two basic types of outposts: general outposts and combat outposts.

GENERAL OUTPOSTS

A general outpost normally is established on orders from the division commander. He prescribes the location, the general composition, and the units responsible for the organization of the general outpost.

The mission of the general outpost is to delay and disorganize the advance of the enemy; and to deceive him as to the true location of the battle position.

The general outpost consists of security elements, a line of support, and a reserve. The security elements may consist of patrols, detached posts, sentinels, and outguards. The support is the principal echelon of resistance of the outpost. The general outpost is usually established from 2000 to 6000 yards forward of the main body. A general outpost normally consists of larger forces than are available to a battalion; therefore, general outposts normally play no part in battalion combat operations.

COMBAT OUTPOST

A combat outpost covers the foreground of the battle position. It is normally established by the battalion and is the foremost element of the command.

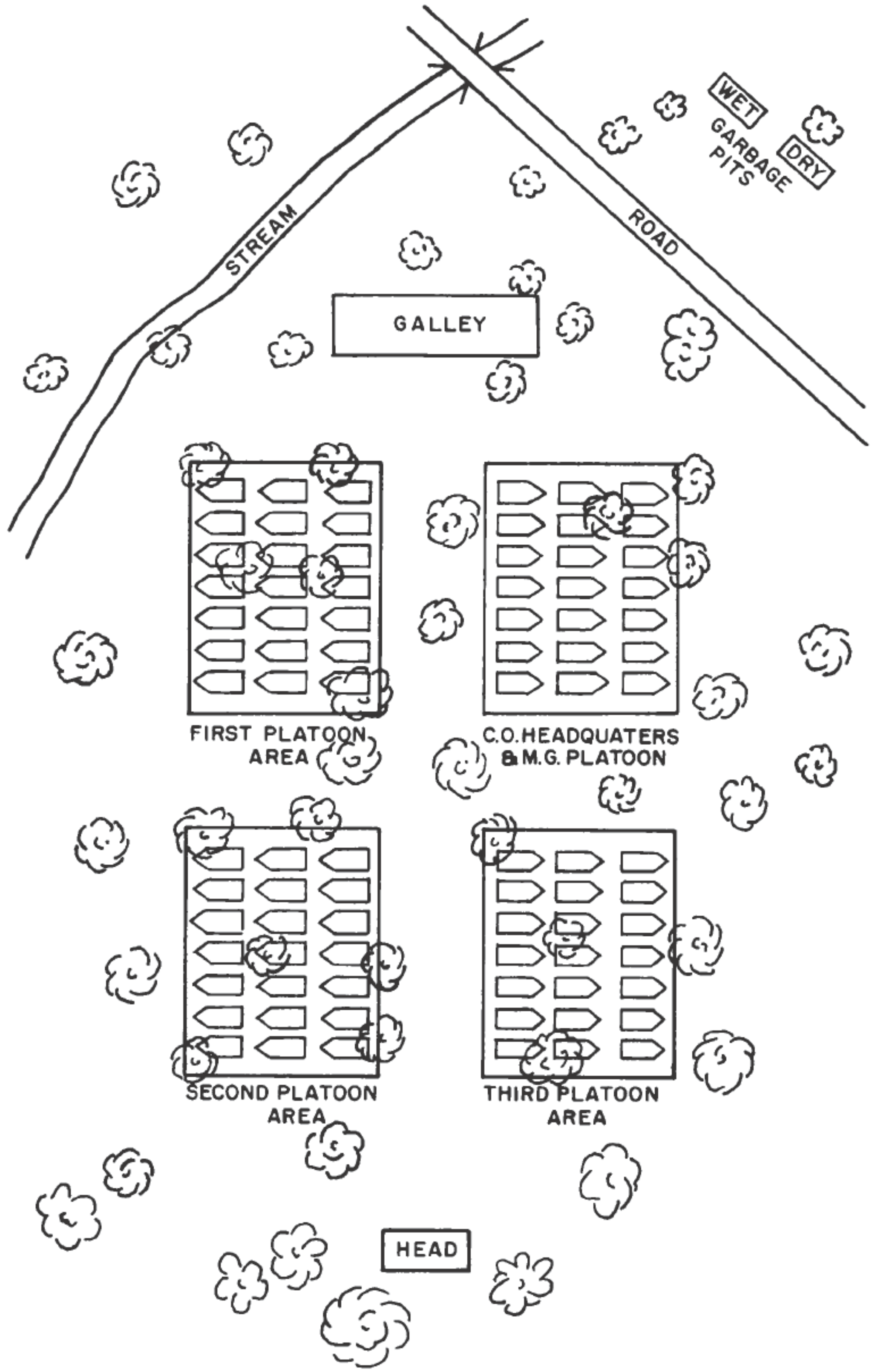

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Figure 2-5.—Sample Bivouac Site.

The mission of the combat outpost is to delay and disorganize the advance of the enemy and to deceive him as to the true location of the battle position. In accomplishing this mission it inflicts the maximum casualties on the enemy without engaging in close combat.

The battalion commander normally prescribes the general location, strength, and composition of the combat outpost. It is usually established from 800 to 2000 yards forward of the main body. Personnel to man the combat outpost are normally drawn from the reserve company or from the front-line units, depending upon the requirements and the tactical situation.

The establishing commander normally controls the combat outpost, and coordinates its actions with his own and adjacent units.

The general line selected for the combat outpost should afford long-range observation. It should be far enough forward to deny the enemy close ground observation of the battle position.

The combat outpost is usually organized in one echelon as a series of outguards with appropriate sentinels and patrols. It maintains contact with security forces to the front (if any) and flanks, and with the battle position (fig. 2-6).

Elements of a Combat Outpost

If the outpost is established less than 800 yards from the battle position the battalion commander may order front-line companies to outpost their respective fronts. The combat outpost for each battalion varies in size. It ranges from a platoon to a rifle company reinforced with supporting arms.

The outguard of a combat outpost varies in strength from four men to a platoon, depending on its location and the number of sentinels it is to furnish. Outguards must be ready for action at all times. Although their primary mission is observation, they will normally fire on small hostile reconnoitering groups.

Sentries to observe to the front of an outpost position are furnished by the outguards. These sentries have the mission of discovering hostile activity, giving the alarm in case of attack, and carrying out other orders specifically prescribed for their posts. Sentries are generally posted in pairs.

Outposts conduct reconnaissance within the limits required by their security mission. Patrols execute reconnaissance in advance of the line of sentinels and in areas not covered by sentinels. Patrols also maintain contact between elements of the outposts. Patrolling in front of the line of observation is increased at night or during periods of low visibility. Night patrolling requires systematic organization, careful preparation, and coordination.

RELIEF

The outpost of a small command is usually relieved daily. That of a large force may remain on duty for several days. An outpost should not be relieved when a hostile attack is probable since new troops might not have time to organize and become familiar with the terrain and situation before being engaged.

PATROLLING

A patrol is a detachment of troops sent out from a larger body on a mission of combat, reconnaissance, security, or contact with friendly units. There are two general classes of patrols—reconnaissance and combat—either of which might have a mission of security. The classification is derived from the mission assigned a patrol. In the Seabees you are primarily concerned with defensive combat; therefore, in training your men in patrolling, the emphasis should be on reconnaissance and security patrolling which is covered in the Defensive Tactics chapter in the 3&2 Group VIII rating training courses.

COMBAT PATROLS

Combat patrols are assigned missions which usually require them to engage actively in combat. They are fighting patrols.

Every combat patrol, no matter what its specific mission, has a secondary mission—that of gaining information about the enemy and the terrain.

A combat patrol might be dispatched with the mission of:

Capturing prisoners.

Destroying an enemy approaching your installation.

Protecting the exposed flank of a unit.

Seizing and holding commanding ground to prevent enemy occupation.

Clearing isolated groups of the enemy from an area controlled by friendly troops.

Ambushing the enemy.

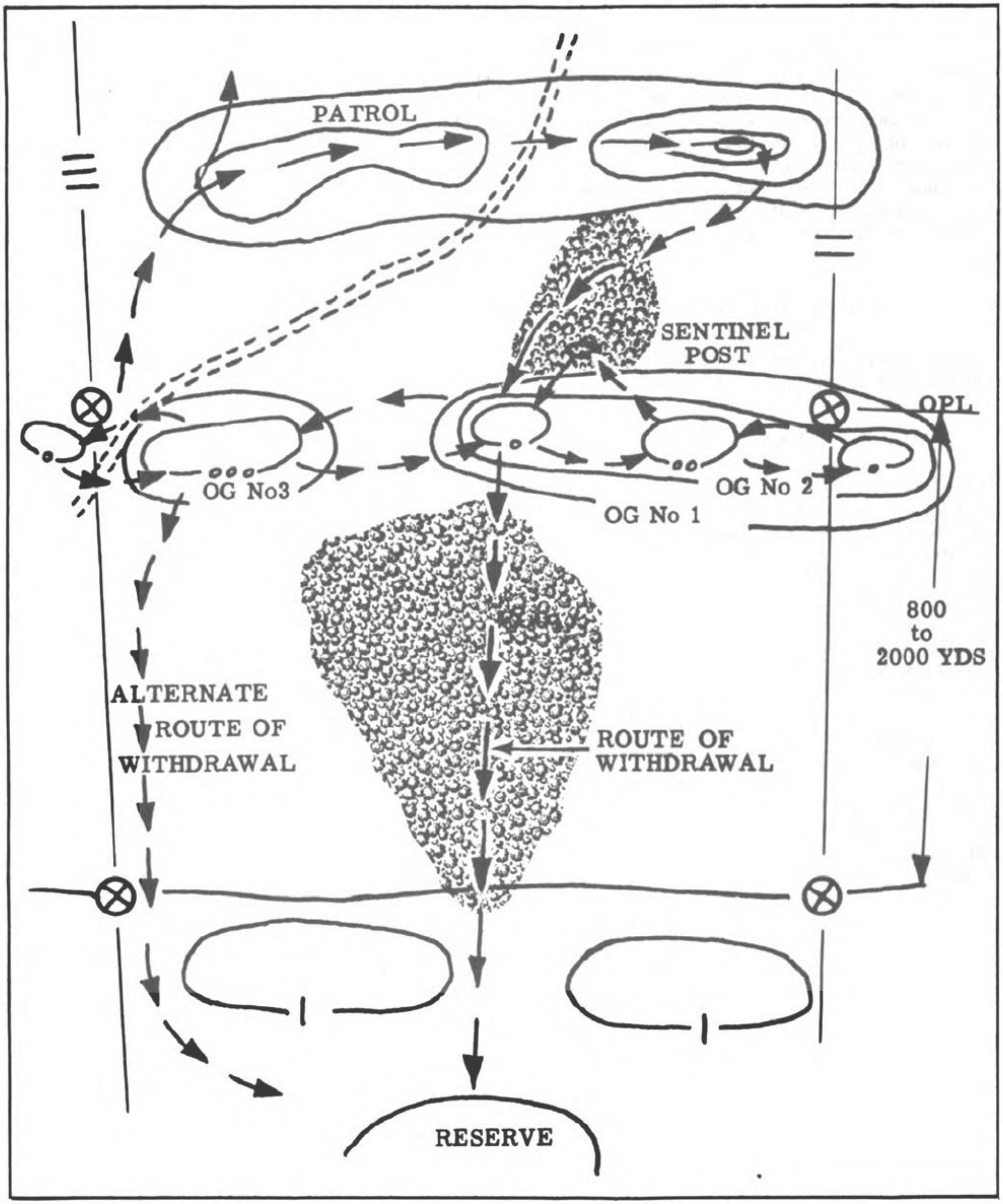

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Figure 2-6. Combat Out Post (Schematic).

Performing other duties involving probable combat.

Both combat and reconnaissance patrols are used by the infantry commander to gain much of the information he needs about the enemy and the terrain. This information enables the commander to carry out his assigned mission more efficiently and effectively.

Information is the framework upon which tactical plans are built. Patrols are one of the most effective information gathering agencies.

FIRE TECHNIQUES

The technique of fire is the application and control of the combined fire of a fire unit.

FIRE CHARACTERISTICS

The fire of rifles and machine guns has the following characteristics: trajectory, danger space, burst of fire, dispersion, shot patterns, and beaten zone.

The TRAJECTORY is the curved path of the bullet in its flight through the air. Trajectory is influenced by three forces: velocity of the projectile, gravity, and air resistance. The farther the bullet travels, the greater becomes the curvature of its path. The highest point on the trajectory (called the maximum ordinate) is a point at approximately two-thirds of the range from the weapon to the target (see fig. 2-7).

DANGER SPACE is the area between the weapon and the point of impact in which the bullet does not rise above the average height of a man (presumed to be 68 in.). At ranges up to 750 yd a rifle bullet fired over level or uniformly sloping ground does not rise above this height; therefore, for such ranges danger space is continuous. At ranges greater than 750 yd a portion of the trajectory is above this height and danger space is therefore not continuous, but exists for a variable distance in front of the muzzle and in front of the point of impact—in the latter case beginning again when the bullet comes within 68 in. of the ground. The length of the two danger space zones is dependent upon the range, as shown in figure 2-8.

A number of shots fired automatically with a single pressure on the trigger is called a BURST OF FIRE. For normal ground targets the number of rounds in a burst is usually from 4 to 10.

When several bullets are fired from a rifle or machine gun held in a fixed position, there is a slight variation in the trajectories. This is due to differences in powder charge, weight of bullet, atmospheric and wind conditions, and vibration of the weapon. These variations are known as DISPERSION. The several dispersions, plotted in profile, form a cone with apex at the muzzle of the weapon; this is known as the cone of dispersion or cone of fire (see fig. 2-9).

The impact pattern of the cone of dispersion on a vertical target (which would be oval in shape) is called the VERTICAL SHOT PATTERN. (See fig. 2-10.) The impact pattern on a horizontal target (which would be a long, narrow ellipse) is known as the HORIZONTAL SHOT PATTERN or BEATEN ZONE. (See fig. 2-11.)

The BEATEN ZONE is the area of the ground struck by the bullets. The size and shape of the beaten zone depend upon the range and slope of the ground, as shown in figure 2-12.

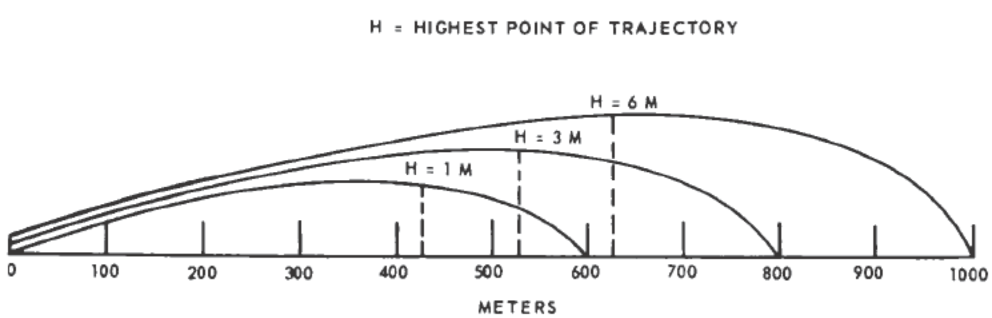

Figure 2-7. Projector of 7.62-MM Ammunition Showing Maximum Ordinate (H) of Trajectory.

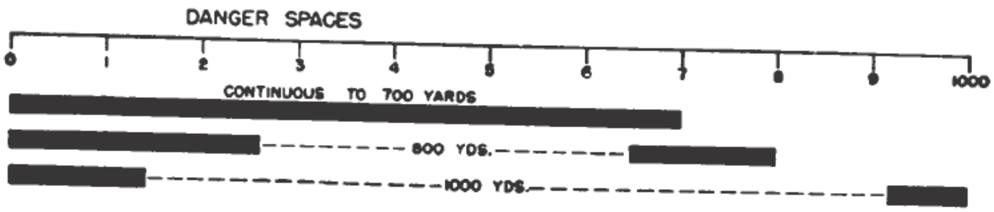

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Figure 2-8.—Danger space at 1000-yard range.

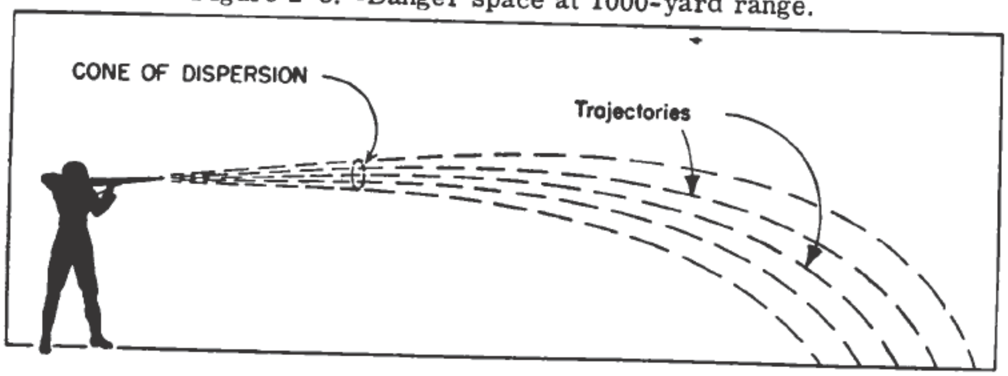

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Figure 2-9.—Cone of dispersion or cone of fire.

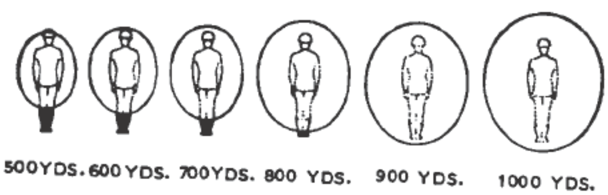

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Figure 2-10.—Vertical shot pattern at various ranges.

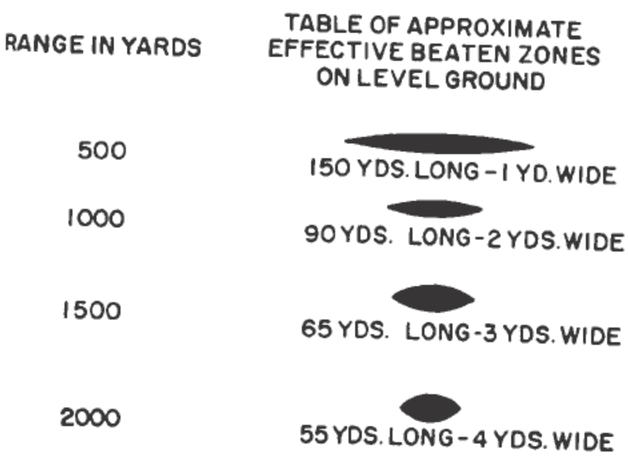

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Figure 2-11.—Horizontal shot patterns at various ranges.

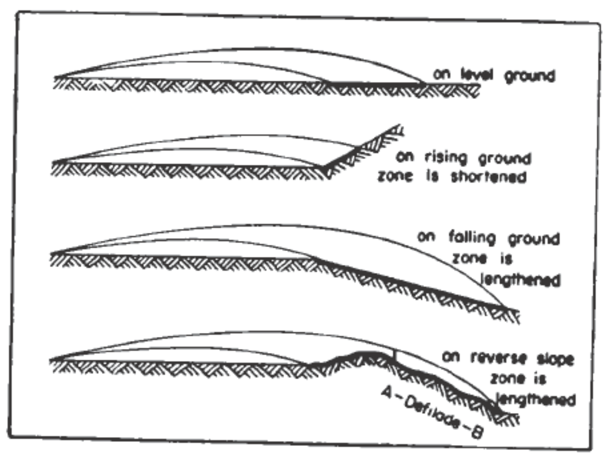

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Figure 2-12.—Effect of ground slopes on beaten zone.

CLASSES OF FIRE

Fire is classified with respect to the target, the ground, and the gun.

Fire with respect to the target may be FRONTAL (delivered perpendicular to the enemy front), FLANKING (delivered perpendicular to the enemy flank), or ENFILADE (delivered in such a manner that the long axis of the beaten

zone corresponds with the long axis of the target). Enfilade fire may be either frontal or flanking, depending on the direction of the long axis of the target. Since it makes maximum use of the beaten zone in relation to the shape of the target, it is the most effective fire. Fire delivered from a direction which is neither frontal nor flanking is called OBLIQUE fire. (See figs. 2-13 through 2-15.)

Fire with respect to the ground may be:

GRAZING, fire in which the trajectory is not higher than 68 in. Grazing fire can exist for 750 yd over level or uniformly sloping ground.

PLUNGING, fire which strikes the ground from above at a considerable angle. In plunging fire the danger space is practically limited to the beaten zone.

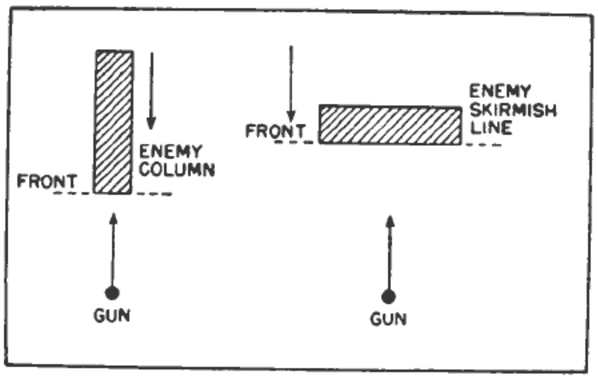

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Figure 2-13.—Frontal fire against an enemy column (on the left) and an enemy skirmish line (on the right).

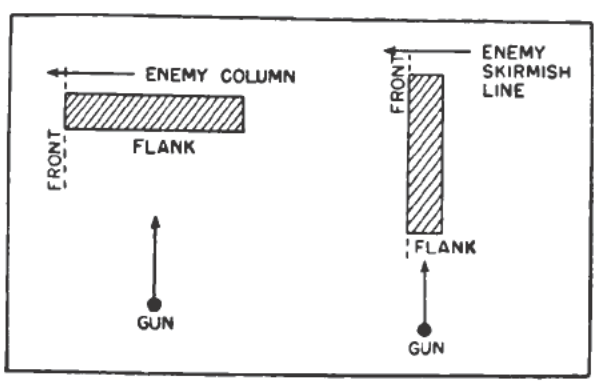

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Figure 2-14.—Flanking fire against an enemy column (on the left) and an enemy skirmish line (on the right).

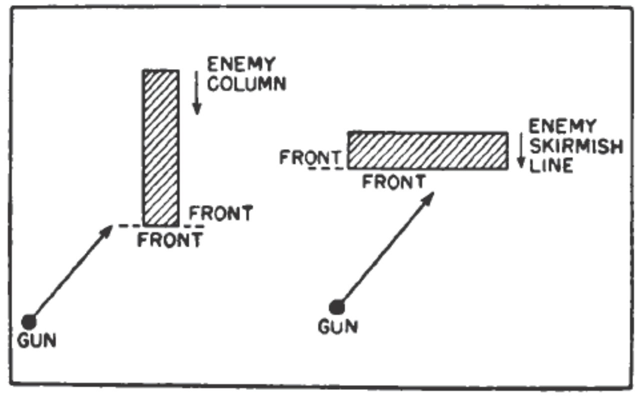

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Figure 2-15.—Oblique fire against an enemy column (on the left) and an enemy skirmish line (on the right).

OVERHEAD, fire delivered over the heads of friendly troops. It must usually be high trajectory, plunging fire.

Fire with respect to the machine gun may be fixed fire, searching fire, traversing fire, or combined traversing and searching fire.

FIXED FIRE is fire delivered on a point target. The depth of the beaten zone must be sufficient to include the target. Fire is continuous as long as any portion of the target remains in the zone of fire.

SEARCHING FIRE is fire distributed in depth by successive changes in elevation of the gun. Searching fire is used against targets too deep to be included in the beaten zone of fixed fire. A burst of fire is delivered after each change in elevation.

TRAVERSING FIRE is fire distributed in width by successive changes in the horizontal direction of the gun. A burst of fire is delivered after each change, or during the swing.

COMBINED TRAVERSING AND SEARCHING FIRE is fire distributed both in width and depth, by changes in both elevation and horizontal direction.

OVERHEAD FIRE

Overhead fire with the rifle is safe when the ground affords protection to friendly troops, or when the troops are sufficiently below the line of fire. Whether or not it should be used in any particular case is a matter of judgment.

A machine gun on a tripod is capable of delivering accurate overhead fire because of the small and uniform dispersion of the cone of fire. In the attack, the use of overhead fire permits the machine gun to support the advance of rifle units. To permit overhead fire on any target, the cone of such fire must pass over the heads of friendly troops by a certain distance, called the MINIMUM CLEARANCE. There are two rules by which the prescribed minimum clearance may be determined: the GUNNER'S RULE, for ranges up to 900 yards, and the LEADER'S RULE for ranges greater than 900 yards. Overhead fire will not be delivered, by use of these rules, at ranges less than 400 yards or greater than 1800 yards.

Steps in the application of the GUNNER'S RULE are:

1. Lay the gun on the target, with the correct sight setting to hit the target.
2. Without disturbing the lay of the gun, set the rear sight at 1500 yards.
3. Look through the sights and note the point where this new line of air strikes the ground. If this point is beyond the feet of friendly troops, overhead fire may be delivered safely until the troops reach the point; it is not safe to fire when they pass this point (see fig. 2-16).

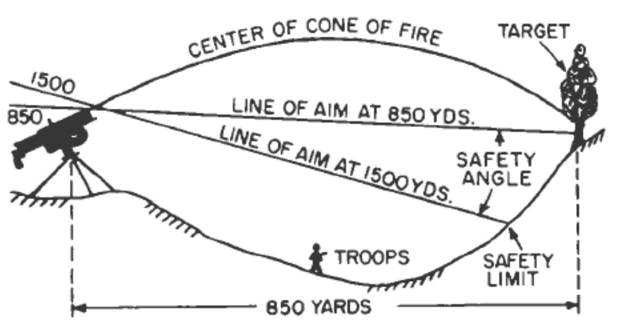

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Figure 2-16.—Application of gunner's rule.

Steps in the application of the LEADER'S RULE are:

1. Select a point on the ground to which it is believed friendly troops can advance with safety.
2. Determine the range to this point by the most accurate means available.
3. Lay the gun on the target with the correct sight setting to hit the target.
4. Without disturbing the lay of the gun, set the rear sight at 1500 yards, or at the estimated range to the point plus 600 yards, whichever is greater. Under no condition should the sight setting be less than 1500 yards.
5. Note the point where the new line of aim strikes the ground. If it strikes at the selected point, that point marks the limit of safety.
6. If the new line of aim strikes the ground short of the selected point, it is safe for troops to advance to the point where the line of aim strikes the ground, and to an unknown point beyond. If it is desired to fire after friendly troops advance farther than the point where the line of aim strikes the ground, this farther point must be determined by testing new points until the line of aim and the selected point coincide.
7. If it clears the selected point, it is safe for the troops to advance to the selected point, and to an unknown point beyond. If it is desired to have the troops advance beyond the selected point, this further point must be determined by testing new selected points until the line of aim and the selected point coincide. This point marks the limit of safety.

RANGE ESTIMATION

In combat, ranges are seldom known in advance. In order to bring effective fire to bear on the enemy, riflemen and machine gunners must be trained to estimate ranges quickly and accurately. Ranges are estimated either by eye or by observation of fire.

ESTIMATION BY EYE is the usual method of estimating range in combat. It is accomplished by mentally applying a unit of measure to the distance to the target. This unit is normally 100 yards. It is necessary to be familiar with the appearance of this unit at various distances and over varying types of terrain in order to be able to use it effectively when estimating ranges by eye.

Eye estimation is difficult to apply for ranges more than 500 yards. When the range exceeds 500 yards, estimate a point halfway to the target and then double the estimate.

When much of the ground between the observer and the target is hidden, eye estimation is difficult. In some cases this difficulty may be overcome by the use of a MENTAL ARC. Move your gaze in a mental arc to the right or left of the target until a prominent object at about the same range as the traget, toward which the intervening ground is visible, is picked up.

When none of the previously described methods is feasible, it may be possible for you to estimate the range by the appearance of objects. Conditions of light, atmosphere, color, and terrain affect the apparent distance of objects.

Accurate estimation of ranges by eye requires considerable practice over all types of terrain and under all conditions of visibility. The use of known-distance ranges, marked off in 100-yd intervals, is recommended for initial training.

Range estimation by OBSERVATION OF FIRE is determined by observing the flight of tracer bullets, or by observing the points where projectiles strike.

Tracer bullets leave a red trail for about 950 yards of their flight. The firer first estimates the range by eye to determine the initial sight setting. Thereafter, by watching the strike of the tracer bullets, he corrects the sight setting to hit the target.

In suitable terrain a projectile striking the ground will kick up dust or other visible material. The same procedure used with tracers is followed.

FIRE DISCIPLINE

Fire discipline is the state of order, coolness, efficiency, and obedience existing among troops in a fire fight. It implies the careful observance of instructions in the use of the weapons in combat, and execution of the exact orders of the leader. Fire discipline is necessary for proper control by leaders, and upon this control depends the effectiveness of collective fire. Fire discipline is maintained by unit leaders. The responsibility for fire discipline in the platoon rests with the platoon commander, assisted by his subordinates. Fire discipline in the squad is maintained by the squad leader. There is a tendency for untrained machine gunners and riflemen to open fire at night on noises and other imaginary targets. This is dangerous and wastes ammunition; more important, it gives the position away. The enemy could stand off and send a couple of scouts in to fire several shots or throw some grenades at the defensive positions to draw responsive fire. If the fire discipline is poor, the defenders return the fire. The enemy can then plot the locations of the defense positions, and plan an attack to avoid strong points, or direct supporting fire accurately on the defenders. The squad leader is responsible for preventing such conditions in his squad.

FIRE CONTROL

Fire control includes all operations connected with the preparation and actual application of fire to a target. It implies the ability of the lead er to have his unit open fire at the instant he desires, to adjust the fire of his weapons on the target, to shift fire from one target to another, to regulate the rate of fire, and to cease firing at will. Lack of proper fire control causes loss of the surprise effect, premature disclosure of position, misapplication of fire on unimportant targets, and waste of ammunition. DISCIPLINE and CORRECT TECHNICAL TRAINING are fundamental in assuring fire control.

The platoon commander's order to his section or squad leaders assigns a mission to each section or squad, or gives the firing position area each will occupy and the targets it will engage, or the sector of fire it will cover. In addition, it frequently prescribes the technique to be employed in engaging targets.

The section or squad leader's order prescribes the location for each weapon, the targets to be engaged or sector of fire to be covered, and the technique to be employed.

In the absence of orders from the next higher commander, fire is opened, lifted, shifted, and its rate regulated by platoon, section, or squad leaders.

FIRE DISTRIBUTION

Fire, to be effective, must be distributed over the entire target. Improper distribution results in gaps between zones and allows a part of the enemy to escape, to advance, or to use his weapons without effective opposition.

Rifle Fire

The fire of a rifle unit is either concentrated or distributed. The nature of the target, as given in the fire order, will determine in each rifleman's mind which type of fire to apply.

CONCENTRATED FIRE is directed at a single point. Enemy machine guns, bunkers, and heavy weapons are examples of suitable targets for concentrated fire.

DISTRIBUTED FIRE is fire distributed in width for the purpose of keeping all parts of a larger-than-point target under effective fire. Each rifleman fires his first shot at that portion

of the target corresponding generally to his position in the squad. He then distributes his succeeding shots over that part of the target extending a few yards right and left of the point of aim for his first shot. The width of target he will cover will be the maximum on which he can deliver accurate fire without changing his position, as shown in figure 2-17.

fire neutralized. It does little good to pin down only the obvious positions and allow the remaining enemy to fire unmolested.

Under these circumstances, to effectively apply the proper fire distribution, the unit leader must first determine the locations of the enemy's flanks. The flanks may be obvious and easily seen; they may be limited by natural features such as woods, a cliff, or a gully; or they may be approximately located from the direction and sound of the enemy's firing.

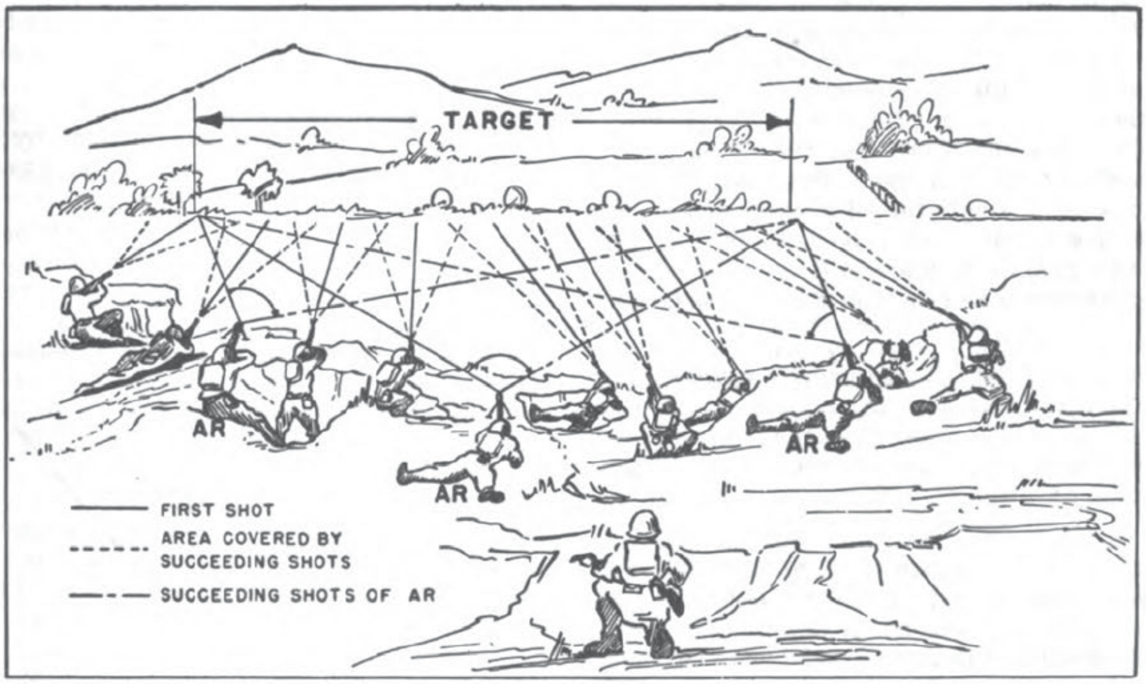

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Figure 2-17.—Fire distribution by individuals of the rifle squad.

In PLATOON FIRING, unless otherwise ordered, each squad completely covers the target designated for the platoon. This enables the leader to shift part of his fire to a new target, or to remove a squad from the line, without leaving a portion of the target no longer under fire. If it is not desired that each squad cover the entire platoon target, the platoon leader assigns definite sectors of fire to each squad.

In DETERMINING EXTENT OF TARGET, it is difficult or impossible to pick out visually each individual enemy in a dug-in and/or camouflaged position. A few individual positions may be located by muzzle blast, but many will be too well camouflaged to be seen. It is, however, imperative that the whole target be engaged if decisive casualties are to be inflicted and the enemy

Having determined the flanks, the squad leader must designate that portion of the target, whether in part or in its entirety, which he wishes his squad to engage. This can best be done by the use of tracers fired on either flank. The squad then opens fire using the normal fire distribution.

Machine Gun Fire

In fire control terminology, target width is designated in MILS. The mil, is a unit of angular measurement, there being 1600 mils in 90 degrees. Gun angles of train and elevation are measured in mils. Now, a target width of (say)

50 mils has no relationship to the actual width of the target; this expression simply means that moving the gun through a train angle (horizontal angle) of 50 mils will cover the entire target front. Thus, as you can see, a very wide target could have a target width of 50 mils at long range, while a very narrow target would have the same width at much shorter range.

No fixed rule as to the maximum width of a target that may profitably be engaged by a single gun can be given. It is preferable, though, that targets for light machine guns be less than 50 mils in width. The section (two guns) is the machine gun fire unit. Whenever practicable, both guns should be assigned the same target area, although occasions may arise when single guns may profitably be employed. The assignment of both guns to a single target area ensures continuous fire should either be put out of action, provides a greater volume of fire on the target, and reduces the time required to cover the target.

Targets having a width or depth no greater than the beaten zone of the weapon engaging them are considered POINT targets. They should be engaged by fixed fire, the command for which is: FIXED. Gun crews are trained to follow any movement or change in formation made by the enemy after the initial burst of fire.

When sections engage frontal targets which are less than 50 mils wide and less than the length of the beaten zone in depth, the normal traversing method is used. Each gun is laid just outside its corresponding target flank, and traversed across the target front to a point just outside the opposite target flank. (see fig. 2-18.) The command for this type of fire is: TRAVERSE.

When the target measures 50 mils or more in width, and is less than the length of the beaten zone in depth, the leader assigns a portion of the target to one gun and the remainder to the other. Each gun lays on the outside flank of its assigned portion, and traverses back and forth across the portion assigned. (see fig. 2-19.) The command would be, for example: No. 1 gun, RIGHT HALF; No. 2 gun, LEFT HALF; TRAVERSE.

If the flanks of the target cannot be seen, each gun should be ordered to traverse so many mils from a point between the flanks. The designated number of mils should be such as to cause each gun to traverse to a point beyond the suspected flank.

Searching fire is used to cover targets deeper than the length of the beaten zone. If the target is stationary, has limited mobility, or is moving slowly, and if the ends are visible, No. 1 gun is laid on the near end and searched up, while No. 2 is laid on the far end and searched down. If the depth of the target is estimated as 200 yd or less, the range announced for both guns is that to the middle of the target. If the depth of the target is estimated to be more than 200 yd, the range to the near end is announced for No. 1 gun, and that to the far end for No. 2. The command for this type of fire is: SEARCH.

If the target is moving rapidly toward the guns, both guns are laid on the near end with the range to that point and search up. If the target is moving rapidly away from the guns, both guns are laid on the far end and search down. The distribution element of the command for covering a rapidly approaching or receding target is: ALL GUNS, NEAR (FAR) END, SEARCH.

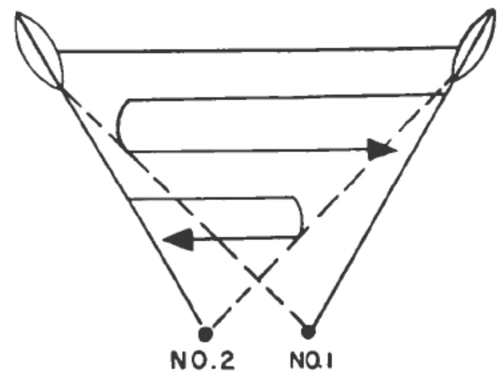

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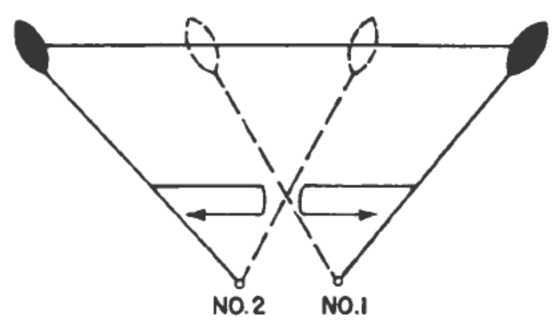
Figure 2-18.—Traversing method by section. Both flanks visible to gunners. Target less than 50 mils in width.



117.156
Figure 2-19.—Traversing method by section. Targets 50 mils or more in width. (Each gun assigned a portion of the target.)

FIRE COMMANDS

The leader of a fire unit, having made the decision to fire on a target, must give instructions as to how the target is to be engaged. These instructions are given in the form of a fire command. A fire command for machine guns contains four basic elements: the ALERT, the TARGET DESIGNATION, the METHOD OF FIRE, and the command to OPEN FIRE.

The alert designates the gun crew that is to fire and alerts them to receive the command. It includes the following:

Gun crew to fire.—FIRST SECTION

Target alert.—FIRE MISSION (with STATIONARY TARGET, MOVING TARGET, or other additional information as appropriate

Target designation is given as follows:
Direction.—FRONT

Target description.—COLUMN OF TROOPS

Range.—FIVE FIVE ZERO (yd)

The method of engaging is designated by naming the method, as: TRAVERSE.

The rate of fire is given by stating the amount of fire to be placed on the target, as: 75 ROUNDS PER MINUTE, or, MEDIUM RATE.

The command to open fire is: COMMENCE FIRING, or FIRE. When a large volume of sudden surprise fire is desired, the command may be prefaced by the preparatory command: ON MY COMMAND. The unit leader then waits until all gunners have located the target and aimed before giving the command of execution.

Fire control will also include any necessary adjustment corrections for machine guns, as RIGHT TWO ZERO MILS, ADD THREE MILS.

A fire command for riflemen and automatic riflemen contains six basic elements: the alert, the direction, the target description, the range, the target assignment, and the fire control.

The ALERT brings the unit to a state of readiness to receive further information. If all men in the unit are not to fire, it also designates those who are to fire. If all men are to fire, the command for alert is: SQUAD. If only certain men are to fire, the names of the men are stated after the word SQUAD.

The DIRECTION element tells the riflemen the target direction. It may be given orally, as: RIGHT FRONT, or by pointing or firing in the direction of the target. If the target is not readily visible, a reference point may be used. Such a point is some prominent terrain feature, either natural or artificial, in reference to which the target may be more easily located. The reference point should be well defined and easily recognized. If possible, it should be on a line with and beyond the target, because in this position it is more accurate for a number of men firing from separated positions.

For the sake of brevity, a reference point is designated by the single word REFERENCE, followed by a description of the point, as: FARMHOUSE ON HORIZON. The distance right or left from the reference point to the target may also be given. This distance may be given in FINGER MEASUREMENTS, in which the method is as follows:

1. Hold your hand at arms length, with palm upward and index finger vertical.

2. Close one eye, sight along the sides of the finger so that one edge is on the reference point, and note where the line of sight along the other side strikes the ground. The distance between this point and the target is ONE FINGER. TWO FINGERS, THREE FINGERS, and FOUR FINGERS, are distances similarly obtained, but with the indicated number of fingers up.

TARGET DESCRIPTION should be brief and accurate. A target may be POINT (such as a machine gun), LINEAR (such as a line of skirmishers), or AREA (such as men dispersed through a clump of woods) in nature.

RANGE may be announced orally or indicated by arm-and-hand signals.

TARGET ASSIGNMENT designates who is to fire at the target. If the whole unit has been alerted, and if it is desired that they all fire, then target assignment may be eliminated.

The FIRE CONTROL element normally consists of the command COMMENCE FIRING or FIRE, plus any desired designation as to rate of fire, such as QUICK FIRE, FIRE FASTER, FIRE SLOWER.

The following is an example of a simple fire command:

SQUAD
RIGHT FRONT
SNIPER ON ROOF OF FARMHOUSE
TWO HUNDRED
JONES AND SMITH
COMMENCE FIRING

An example of a fire command using a reference point and finger measurements follows:

LEFT FRONT
REFERENCE: WHITE CHURCH SPIRE ON HORIZON, RIGHT THREE FINGERS
TARGET: MACHINE GUN IN BUSHES
THREE HUNDRED
TEAMS ONE AND TWO
COMMENCE FIRING

APPLICATION OF FIRE

Application of fire consists of placing the fire of a unit on the desired target at the proper time, and the control of the fire thereafter. Accurately controlled fire on the enemy has both a physical (casualty producing) and a morale effect.

FINAL PROTECTIVE LINES

A final protective line is a predetermined line along which, in order to stop enemy assaults, interlocking bands of grazing fire are placed, fixed as to elevation and direction, and capable of being delivered under any condition of visibility.

When, because of irregularities in the terrain, fixed machine gun fire cannot produce the maximum effective grazing fire, then rifle fire may be employed to ensure that all the final protective lines are covered.

Fire on the final protective line during periods of good visibility is aimed and adjusted fire. Under such conditions, the section leader will generally determine the rate of fire and may also give the order to cease firing.

Under conditions of poor visibility the battalion order may prescribe the rates of fire. In the absence of instructions, the usual rate of fire for a section on a final protective line is the rapid rate for the first 2 minutes, then the medium rate until ordered to cease firing.

OPERATION ORDERS

An operation order puts an operation plan into effect. An operation plan is a detailed statement of the course of action to be followed to accomplish a prescribed or anticipated mission. It is the formal statement issued by a commander to subordinate commanders to outline the coordinated execution of an anticipated operation in the field.

In five paragraphs, operation plans and orders detail the complete information and orders necessary to implement the decision of the commander. They are written so subordinate units and agencies will have a thorough understanding of the part each is to play in the operations.

Operation orders may be oral, dictated, or in written form. The most important factor influencing the form and method of issuing an operation order is the time available for its preparation and distribution. An order should reach its destination in sufficient time to obviate halting the troops while waiting for instructions. Time should also be sufficient to permit the lowest subordinate commander concerned an opportunity to reconnoiter, place his troops in position, make other necessary arrangements, and issue his own orders prior to the hour set for the beginning of the action.

Oral and dictated orders are similar in that both are spoken orders. When oral orders are issued, notes are made by the recipients. Dictated orders are recorded verbatim by the receiver and a complete copy of the order or notes is kept by the staff of the issuing commander.

Written orders may be in message or other convenient form. The use of accompanying maps, photomaps, overlays, and tables saves time and words and minimizes errors. In many cases an entire operation order can be placed on a map or overlay.

Operation orders may be either complete or fragmentary.

An order is COMPLETE when it covers all essential aspects and phases of the operation. Complete orders include missions to all subordinate units charged with the execution of tactical operations in carrying out the commander's plan.

FRAGMENTARY orders are used when speed in delivery and execution is imperative. Fragmentary orders are issued successively as the situation develops and decisions are made, and consist of separate instructions to one or more subordinate units prescribing the part each is to play in the operation or in the separate phases thereof. They may be issued directly to subordinate commanders, or to their representatives; or they may be transmitted by means of signal communication or by special messengers. When transmitted orally, the instructions should be followed, if practicable, by a written confirmation. When conditions permit, special messengers are used for the delivery of oral or fragmentary field orders. Fragmentary orders may be either oral or written; they may be accompanied by maps, sketches, or overlays, or they may consist of maps, sketches, or overlays with written instructions thereon. They are concise but not at the expense of clarity or omission of essential information. Instructions issued in fragmentary orders may be repeated in a complete operation order or in an annex if considered desirable.

FORM OF OPERATION ORDERS

The HEADING contains the security classification, a statement concerning change from oral orders, copy number (hand-written), issuing headquarters, the place of issue, date and time of issue, file notation, title and serial number of the order, references (maps, charts, and photomaps), and the time zone to be used throughout the order. If used, the code name of the operator will follow, and be on the same line as, the operation order title and number.

The BODY contains the task organization (when too complicated or lengthy to be contained in par. 3) and five main numbered paragraphs. The five paragraphs cover the following topics: situation, mission, execution, administration and logistics, and command and communications-electronics. A simple code word that will help you remember these topics is SMEAC, utilizing the first letter of each topic. It must be remembered that the five main topics of an operation order must be covered whether the order is from a battalion commander, platoon commander, squad leader, or a fire team leader. Naturally battalion operation orders are quite lengthy whereas a patrol leader's order is usually brief. A format of a patrol leader's order is shown in figure 2-20. A patrol leader's order is usually oral, with the patrol members taking notes.

The task organization includes the task subdivisions or tactical components which comprise the command together with the names and grades of the commanders. Units in support are shown under the headquarters of the major unit which commands them, not under the headquarters the unit supports. Attached units are shown under the headquarters of the unit to which attached. Units should be listed under paragraph letters which correspond to those in paragraph 3. Only the task subdivisions on the echelon of command next below the issuing unit are normally shown.

Paragraph 1 (situation) always has three subparagraphs: enemy forces; friendly forces; and attachments and detachments. This paragraph contains information only. It does not include plans or instructions.

Paragraph 1a (enemy forces) contains information of the enemy such as composition, disposition, location, movements, strength, identification, and capabilities. It refers to the intelligence annex, periodic intelligence reports, or the intelligence estimate when issued. Distinction should be made between factual information and conjecture.

Paragraph 1c (attachments and detachments) contains a list of nonorganic units attached to, and organic units detached from the command for the specific operation. It includes the date/time the attachment or detachment will take place.

Paragraph 1d (assumptions) is included in operation plans, not orders. It states the assumptions used by the commander in arriving at his plan.

Paragraph 2 (mission) contains a concise statement of the mission, and its purpose, of the command as a whole. It includes "what," "when," "how," "where," and as much of the "why," as may be appropriate. There are no subparagraphs.

Paragraph 3 (execution) assigns definite tasks to each element of the command, organic and attached, which will contribute to the accomplishment of the overall mission. There are no restrictions on the number of subparagraphs.

Paragraph 3a (concept of operations) is a clear concise summary of how the commander visualizes the operation will be conducted. This is an amplification of the decision contained in the commander's estimate. It should be as brief as possible, but may be published as an annex if lengthy or detailed. It may be shown on an operation overlay, in which case it need not be written out. If an overlay or annex is used, this paragraph makes reference to such.

Paragraphs 3b, 3c, etc. (tasks for subordinate units) assign separate lettered subparagraphs in alphabetical sequence to each major subordinate element. These subparagraphs correspond to the alphabetical listings in the task organization. Except as outlined below, all instructions to any unit having a tactical mission should appear in the subparagraph of paragraph 3 pertaining to that unit. Subparagraphs which assign tasks to other combat and combat support elements (if applicable) should follow.

The final subparagraph, always entitled Coordinating Instructions, contains the details of coordination and the control measures applicable to the command as a whole; for example, objectives, comments qualifying time of attack, line of departure, boundaries, beaches, bomb line, and reference to march table annex. Many of these, and other instructions applicable to two or more elements of the command, may be indicated in an attached overlay. In this case they need not be repeated here. Included also in this paragraph might be essential elements of information (unless an intelligence annex is issued),

PATROL LEADER'S ORDER

1. SITUATION

   a. Enemy Forces: Weather, terrain, identification, location, activity, strength.

   b. Friendly Forces: Mission of next higher unit, location and planned actions of units on right and left, fire support available for patrol, mission and route of other patrols.

   c. Attachments and Detachments.

2. MISSION - What the patrol is going to accomplish.

3. EXECUTION - (Subparagraph for each subordinate unit.)

   a. Concept of operation.

   b. Specific duties of elements, teams, and individuals.

   c. Coordinating instructions.

      (1) Time of departure and return
      (2) Formation and order of movement
      (3) Route and alternate route of return
      (4) Departure and reentry of friendly area(s)
      (5) Rallying points and actions at rallying points
      (6) Actions on enemy contact
      (7) Actions at danger areas
      (8) Actions at objective
      (9) Rehearsals and inspections
      (10) Debriefing

4. ADMINISTRATION AND LOGISTICS

   a. Rations.

   b. Arms and ammunition.

   c. Uniform and Equipment (state which members will carry and use).

   d. Method of handling wounded and prisoners.

5. COMMAND AND SIGNAL

   a. Signal.

      (1) Signals to be used within the patrol.

      (2) Communication with higher headquarters - radio call signs, primary and alternate frequencies, times to report and special code to be used.

      (3) Challenge and password.

   b. Command.

      (1) Chain of command.

      (2) Location of patrol leader and assistant patrol leader in formation.

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Figure 2-20.—Format for patrol leader's order.

operational reports to be submitted (if not set forth elsewhere by SOP or special order), preparatory fire information, and the effective time of the order.

Paragraph 4 (administration and logistics) contains administrative and logistic instructions, if an administrative order is not issued. If issued, this paragraph refers to that order. In small commands, such as a mobile construction battalion, this paragraph contains all necessary information and instructions concerning supply, evacuation and hospitalization, transportation, service, personnel, and other such matters.

Paragraph 5 (command and communications-electronics) contains instructions concerning command, command relationships, and the operations of communications and electronics.

Paragraph 5a may refer to a standard plan or to a communications-electronics annex, if issued. If not issued it should contain: references to the index of communications operations instructions (COI) currently in effect, instructions on the use of radio and pyrotechnics, and restrictions on the use of any means of communication.

Paragraph 5b gives the location of the command post of the issuing unit and those of subordinate units when known. When not known, instructions concerning the reporting of command posts when opened may be included.

Paragraph 5c shows the axis of communications (indicated by successive tentative command post locations), and the location and time of opening of message centers.

Also included may be subparagraphs concerning recognition and identification instructions, electronic policy, code words, liaison, and command relationships. Most items in paragraph 5 can usually be shown graphically on the operation map or overlay. If this is done, they need not be repeated in writing.

The ENDING of an operation order contains the signature, a list of annexes (if any), the distribution, the authentication (except on the original), and the classification.

ANNEXES TO OPERATION ORDERS

Annexes accompanying operation orders include those for purposes of brevity, clarity, and simplicity (for example, maps and overlays), and those used to amplify an order when the volume is too great for inclusion in the order itself.

Annexes are issued to all units whose actions or movements are affected by the information and instructions contained therein.

Written annexes usually follow the form prescribed for the complete operation order, except that information and instructions already given in the order need not be repeated in an annex thereto. They are lettered alphabetically in the order mentioned in the operation order.

Maps of the following types are frequently used as annexes: situation maps, operation maps, administrative maps, circulation maps.

Annexes dealing with embarkation, debarkation, entraining, entrucking, march tables, and other technical data are shown in tabular form.

Annexes are prepared by the appropriate staff officers and submitted to the commander for approval and signature prior to issue. They are authenticated by the appropriate staff officer.

PREPARING OPERATION ORDERS

Orders must be clear, concise, and direct. Those giving missions for subordinate units should prescribe only such details or methods of execution as are necessary to ensure that the actions of the subordinate unit concerned will conform to the plan of operations for the force as a whole. The abbreviated form of order with map or overlay is often used.

Paragraphs 1 and 2 of an operation order are usually written in the present tense. In the interests of simplicity and clarity, the affirmative form of expression is used throughout the order.

When the date and hour are undetermined, D-day and H-hour may be used, and the selected date and hour communicated later to those concerned.

When the hour is expressed, it will be in the 24-hour-clock system.

Whenever orders apply to units in different time zones, Greenwich Civil Time or the time zone specified by higher headquarters will be used. The zone suffix letter will immediately follow the last digit of the group. For example, 060225Z, March 64, will indicate 2:25 A. M., March 6, 1964, Greenwich Civil Time.

Dates include the day, month, and year (6 Aug 64). In stating a night, both dates should be included night 4-5 Aug 64).

Boundaries limit zones of action or movement and areas of responsibility. These are designated by easily distinguishable terrain features in the sequence in which they occur on the

ground. This sequence is normally given in the direction of the enemy, but in the case of a retrograde movement, in the reverse direction.

Geographical names are written or printed in capital letters. This minimizes the chance of error and makes the places mentioned stand out prominently in the order. The spelling in the order must be the same as that on the map referred to in the heading of the order.

Compass points are preferable to the terms "right" and "left". Should right or left be necessary, the user is assumed to be facing the enemy, or downstream if used with reference to a river.

When places or features are difficult to find on a map, or when ambiguity may arise with names of similar spelling, they should be identified by coordinates, or by stating locations in relation to some easily distinguishable feature or place on the map.

Roads are identified by name or by a sequence of points on the road, named in the direction of movement, and when there is no movement, from right to left or rear to front, by assuming that the person designating the road is facing the enemy. All other lines are designated in the same manner.

Areas are designated by naming, counterclockwise, a suitable number of limiting points. The first point so named, regardless of whether the area pertains to friendly troops or to the enemy, is one on the right front from the viewpoint of friendly troops.

Expressions like "attack vigorously" are avoided. They are not only meaningless and verbose, but weaken the force of subsequent orders in which the expression does not appear. "Holding attack," "secondary attack," and "main attacks," which qualify the vigor of the operation; and "try to hold" and "far as possible," which lessen responsibility, are further examples of the undesirable phrase.

In operation orders it is essential that there be no opportunity for misunderstanding, by any subordinate, of the exact intended meaning of all terms used. With partially trained troops and staffs, the use of technical military language may afford opportunity for such misunderstandings. Therefore, the use in combat orders of technical expressions should be avoided if there is any danger of misunderstanding. In such cases, words of common understanding should be substituted, even at the sacrifice of brevity. Clarity is the first essential, technique is secondary.

DEFENSIVE COMBAT

The mission of the battalion in defense is to repel and destroy the enemy by fire, close combat, and counterattack.

The method of employment of the battalion to carry out the defensive mission will vary with the construction mission, the size of the battalion, the terrain, and any other items that will effect the employment of the troops. There are many techniques that may be used to carry out the defensive mission. (NOTE: The principles that are followed by the battalion commander in this section apply at all levels.

Because of the variation in operational techniques, battalion commanders must remain flexible and gear their actions to the organization and actions of higher headquarters. They must be prepared to operate in a security, forward defense, or reserve role and they must adjust their thinking to the tactical philosophy of their higher headquarters.

PRINCIPLES OF WAR

The battalion commander may employ the principles of war as modified for the defense. Some of these principles which have particular application in the defense are-

OFFENSIVE.-Throughout the planning and conduct of the defense, an aggressive attitude is retained and opportunities to regain the initiative are sought and exploited.

ECONOMY OF FORCE.—To achieve superior combat power at the point of decision, the commander must necessarily reduce his defensive strength in less critical areas. The arbitrary equal apportionment of defense frontage or use of a set "template" in assigning frontages must be avoided.

SURPRISE.—Surprise can decisively shift the balance of combat power. In the defense it may be achieved by deception; effective combat intelligence and counterintelligence; variation in tactics and methods of operation; and appropriate application of the unexpected, particularly in the counterattack.

SECURITY.—The battalion or its elements should not be presented to the enemy as a fixed, easily located target.

TYPE OF DEFENSE

The type of defense that is most often used in a Seabee battalion is an area defense. The

mission of a battalion will normally be to "build and protect a facility". It is not expected that there will be outside help for the defense of the facility. As an independent unit the best way for a battalion to protect a facility is the area (perimeter) defense.

The area defense is oriented toward the retention of specific terrain. In this type of defense, forward positions are strongly held and emphasis is placed upon stopping the enemy forward of the battle area. The bulk of combat power is committed in the forward defense area. If the enemy penetrates the area, he is destroyed or ejected by counterattack with the principal objective of regaining control of the forward defense area.

THE BATTALION BATTLE AREA

Defensive echelons include the security area, the forward defense area and the reserve area (fig. 2-21). The battalion battle area is that defensive area organized by a single battalion and includes all that area inside the perimeter. Throughout this chapter, when reference is made to the battle area, it is construed to mean battalion battle area unless otherwise indicated.

Security Area

The battalion security area extends from the forward edge of the battle area (FEBA) to whatever distance to the front security elements available to the battalion are employed. Forces in the security area furnish timely information of the enemy; deny him close ground observation of the battle area; and deceive, delay, and disorganize the enemy as much as possible. Security forces in this area may include aerial surveillance, combat outpost, patrols, and local security elements.

Forward Defense Area

The battalion forward defense area extends rearward from the FEBA to include that area organized by the forward committed companies.

Forward defense forces in the area defense engage the enemy in decisive combat in order to retain specific terrain.

Reserve Area

The battalion reserve area extends from the rear of the forward committed companies to the center of the battalion battle area.

Forces in the battalion reserve area eliminate penetrations, block or reinforce threatened areas. They destroy or eject the enemy by counterattack to regain control of the battalion forward defense area.

PLANNING THE DEFENSE

The plan of defense consists of a scheme of maneuver and a plan of fire support. Both are developed concurrently and must be closely integrated. The plan of defense also covers the essential details of counterattack planning, security, administrative support and the establishment of the communication system necessary for control.

The defending force usually possesses, or can gain, the following advantages:

1. Terrain favorable for the defense.
2. Better control and coordination of effort.
3. Maximum effective use of fire power through careful organization of the defense.
4. Added protection by use of field fortifications.
5. Fewer personnel and materiel losses, as a result of the preceding considerations.

The following disadvantages often counterbalance the advantages of the defending force:

1. The attacker has the initiative; he can decide when, how, and in what exact spot the attack will occur.
2. As a result of (1), the defender must spread his forces to defend all possible avenues of enemy attack. The attacker, on the other hand, can mass his forces at one decisive point.

Scheme of Maneuver

The organic maneuver elements of the battalion are the rifle companies and the reconnaissance platoon. The scheme of maneuver is the plan for placement and movement of these and attached maneuver units to accomplish the mission. Throughout the development of the scheme of maneuver the commander considers the mission, enemy, terrain and weather, and troops available (abbreviated METT), and their effect on the plan of defense.

In developing the scheme of maneuver, the battalion commander and staff normally follow a logical planning sequence similar to that outlined below:

1. Analyzes the mission and all available information.

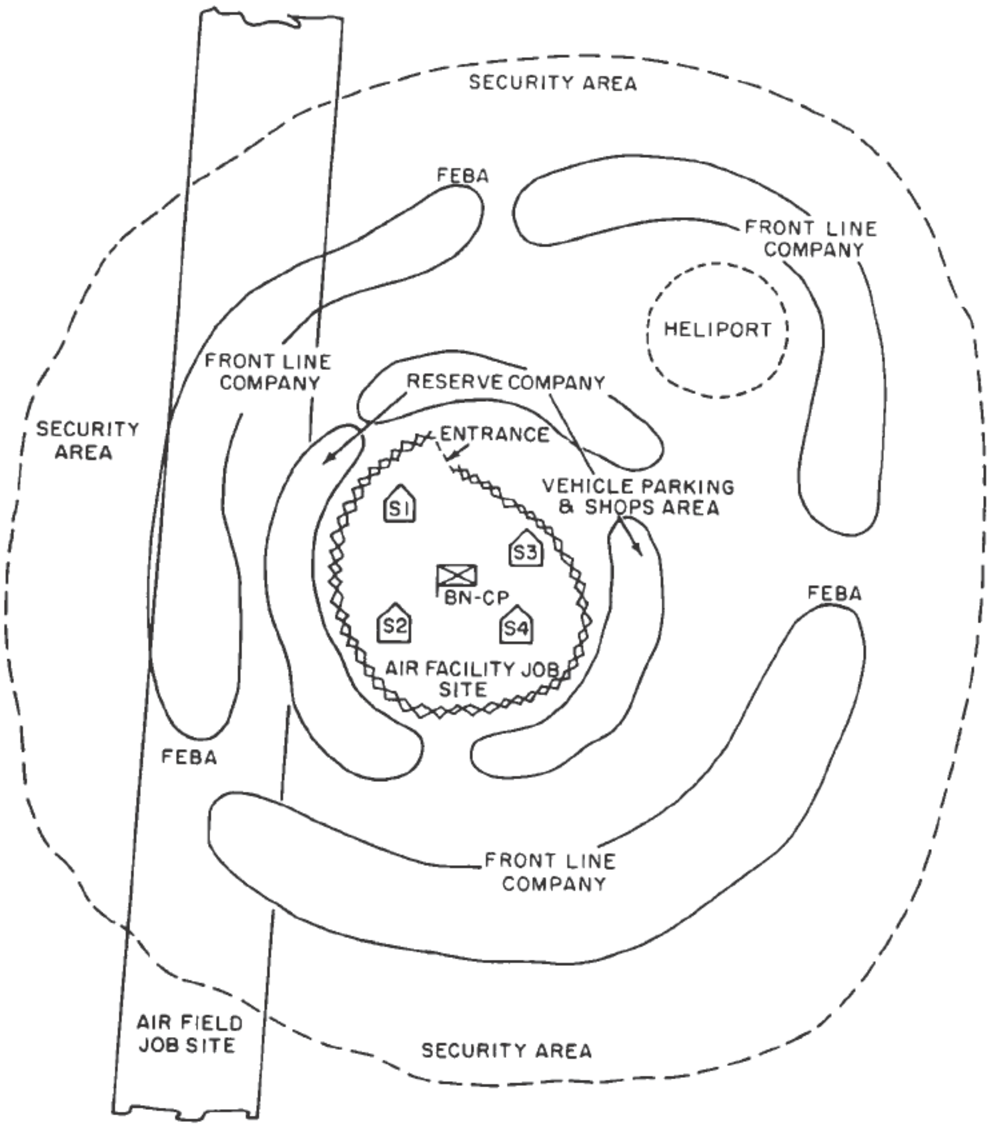

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Figure 2-21.-Battalion battle area.

2. Determines key terrain and major avenues of approach into sector.

3. Determines forces to be employed on FEBA and in reserve.

4. Determines security forces and measures required.

Determines requirements for obstacles, antitank defense, and other defensive measures.

6. Establishes control measures required.

7. Finalizes organization for combat.

8. Determines administrative support requirements.

9. Considers alternate plans for all foreseeable contingencies.

The sequence outlined above is flexible and may be adjusted to the situation, type of operation, or the personality of the commander. Some of the steps may be considered in a different order or concurrently and some be revised as the planning is carried out. In appropriate steps in this sequence, the plan of fire support and the counterattack plan are also considered and developed.

Defensive Mission

The first step in developing a scheme of maneuver is a thorough analysis of the battalion mission and a consideration of all available information of weather, terrain, and friendly and enemy forces. The commander must study his order to insure that he understands all tasks, stated and implied, which the battalion must accomplish.

The battalion commander usually designates the trace of the forward edge of the battle area and the initial location of the combat outpost, when used. He designates the responsibility of the company along the FEBA by specifying the location of company boundaries and coordinating points.

Defensive Sector

The commander performs a detailed reconnaissance of the area by foot, air, or motor vehicle. Based upon this reconnaissance and other information obtained, he analyzes his defensive sector to determine which terrain feature(s) must be controlled by him to accomplish his mission. If the seizure or control of such a feature would afford a marked advantage to either opposing force, it is a key terrain feature and must be controlled by the defender.

The defender is not rigidly bound to physically occupy key terrain features; he may control entry to them or, in conjunction with fires, defend them with comparatively small forces. It may be necessary to defend key terrain features in strength, or the commander may elect or be ordered to relinquish key terrain temporarily as a part of the scheme of maneuver.

After a determination of key terrain, the commander must analyze the avenues of approach into his area from all directions. He also considers avenues of approach to be used by elements of his force in the counterattack. The commander analyzes the observation, fields of fire, concealment, cover, and obstacles in the sector. He also considers possible improvement of the obstacles and the use of barriers to enhance his defense. From this analysis of his defensive area, he determines how he can make best use of the terrain within available resources to accomplish his mission.

Organization

The battalion commander tentatively establishes his organization for combat early in his planning. However, as he continues to develop his scheme of maneuver, he may adjust his allocation of combat power as certain aspects of the defense are considered. When the commander has reached the stage in his planning where his scheme of maneuver is firm, he establishes a detailed organization for combat. The commander may tailor his organic or attached companies by employing them as pure or cross-attached units.

In the position defense there are three tactical groupings: the SECURITY FORCES, the HOLDING FORCES, and the RESERVE. The commander formulates his plans on the following principles: organization of the critical terrain, depth, mutal support, all-around defense, coordinated fire plan, antitank defense plan, and flexibility.

Forces to be Employed

As the commander is analyzing the terrain in his area, he considers the amount of resistance which he desires on each major avenue of approach based upon his visualization of what will be required to hold the terrain or execute the required delay. As one technique, the commander may visualize the number of platoon size units required on the FEBA. From this visualization he then determines the number of companies required and selects tentative lateral boundaries.

The number of companies employed along the FEBA, the width of the sector assigned to each, and the specific locations of blocking positions selected for preparation and occupation (or for preparation and possible future occupation) depends upon the mission; the size, trafficability, and natural defensive strength of the area to be defended; enemy capabilities; and the capabilities of the defender.

Security

In planning his defense, the battalion commander insures that adequate provision is made for all-around security. The combat power allocated to security forces and the measures taken are determined by a consideration of METT.

The security forces usually consist of (1) local security sent out from companies on the FEBA, (2) a combat outpost, located from 800 to 2000 yd forward of the FEBA, manned by men from the reserve company, and (3) local security, for the protection of rear and flanks, manned either by front line or reserve company personnel.

The mission of the security forces is to gain information of the enemy, prevent surprise to the holding forces, delay and disorganize the enemy, deceive him concerning the location of the FEBA, and inflict casualties. Security forces withdraw to the FEBA before the enemy can assault their positions.

Unless deception is an essential element of the defense, the attacking enemy is normally taken under long range fire as early as possible. As he advances, he is taken under increasingly heavy fires. Prior to the time that each of the security elements is forced to withdraw through elements to its rear, they delay, deceive, and disorganize the enemy to the maximum extent possible. They normally do not become decisively engaged, and they fight a delaying action to inflict maximum casualties on the enemy.

Positive measures must be taken against enemy airborne, guerrilla, and infiltrating forces so that the unit can concentrate on its primary mission. A warning system is established throughout the battalion area using security and observation elements already emplaced. Detailed reconnaissance is conducted to locate probable drop and landing zones. Where necessary, special patrols, warning devices, roadblocks, and observation posts with ground radar equipment may be established to cover the area. Measures are taken to provide for security of administrative elements in the area. An illumination plan is prepared. When information indicates that an enemy force has entered the area, all or a portion of the reserve is given the mission of destroying it. Planned fires support the reserve. Other units within the area remain in position and support the reserve by fire.

Frontage and Depth

The battalion commander assigns proportionate frontages to his forward companies according to the natural defensive strength and importance of their defense area. Each company is assigned sufficient frontage and depth to enable it to disperse as the mission will permit.

The battalion is capable of conducting a defense, on ideal terrain with two companies forward, on frontages up to 3000 meters with depths of about 2500 meters. Companies are capable of conducting a defense on ideal terrain on frontages up to 1500 meters with depths of about 1100 meters. These are considered to be the maximum frontages; the frontage will normally be considerably less. Conditions which limit visibility and the fields of fire of the defender, offer good avenues of approach to the enemy, or reduce the combat power of the defender, will habitually reduce this maximum frontage. The actual capability of the battalion in any given situation can only be determined after a complete estimate of the situation.

Companies are not assigned frontages in excess of 1500 meters. When the battalion has a frontage in excess of 3000 meters, it will still occupy only 3000 meters or less of its defensive sector. The additional lateral area will be covered by patrols, fires, observation posts, listening posts, minefields, and other means. In effect, this will result in gaps between companies which must be covered by as many of the above mentioned means as are available. An enemy attack through these gaps must be detected, located, fired upon, and if the need arises, blocked and/or destroyed by the fire and maneuver of all or part of the battalion.

It is desirable for units and weapons to be located and employed so that they can assist one another with direct fire of automatic weapons. As a minimum, mutual support is obtained between companies by the fires of 81-mm mortars.

Care is exercised to insure a proper balance between concentration and dispersion. Dispersed personnel and equipment at every echelon must be capable of accomplishing the mission. The depth of the area assigned to the forward companies is comparatively shallow in relation to the overall depth of the battalion area. However, they are given adequate space to position their weapons, control facilities, and logistical elements, and to establish alternate and supplementary positions.

Forward Defense Forces

The forward defense forces constitute the strongest part of the defense. They man the position on which the main effort is concentrated.

The battle position is composed of a number of subordinate positions, each organized for all-around defense and disposed in width and depth. The subordinate positions are mutually supporting.

The mission of the forward defense forces is to stop the enemy by forward fire, to repel him by close combat if he reaches the line, and to eject him by counterattack if he penetrates it. This is accomplished by locating weapons and assigning fire missions to:

1. Support the withdrawal of security forces.
2. Fire on targets of opportunity as the enemy approaches the FEBA.
3. Ensure that the heaviest fires fall immediately forward of the FEBA. These fires should be mutually supporting, interlocking bands of grazing fire, called FINAL PROTECTIVE fires.
4. Limit penetrations to the FEBA by fires from weapons placed in depth.
5. Support the counterattack in case of enemy penetration.

The Reserve

As the battalion commander is determined the forces required on the FEBA, he concurrently considers the size and location of the reserve. He allocates sufficient combat power to the reserve after a consideration of METT. The reserve is not a residue remaining after allocation of elements to forces on the FEBA. Appropriate missions for the battalion reserve include —

1. Providing the battalion portion of the combat outpost.
2. Preparing and occupying blocking positions.
3. Conducting counterattacks.
4. Assisting forward companies, when practicable, through use of organic fire support.
5. Providing flank and rear area security.
6. Preparing to assume mission of forward company on order.

The reserve position(s) and alternate and supplementary positions are selected so as to provide defense in depth, all-around defense, and flexibility. Positions are on or near key terrain features or on major avenues of approach where penetrations can be blocked.

When the battalion commander requires the reserve to prepare alternate or supplementary positions, he specifies the priority of construction. When the battalion reserve is not working on positions, manning the combat outpost, or performing surveillance missions in the battalion rear area, it usually occupies the reserve positions having the highest priority for defense. These positions may be completely occupied or occupied with skeleton forces, with the remainder of the reserve dispersed in the vicinity.

The reserve must be prepared to move quickly to threatened areas. Transportation may be used to shift reserves rapidly. Vehicles provide a capability to concentrate power rapidly from dispersed positions to participate in a counterattack.

Reserve units organize defensive positions in depth behind the FEBA, but within the battle position. Their primary missions are to support by fire and limit penetrations to the FEBA. Battalion reserves may be held mobile, in covered and concealed positions, ready to counterattack or occupy previously prepared positions when the need arises.

If the enemy penetrates the battle area, the battalion commander uses his reserve to limit the penetration. When there is a reasonable chance of success, he launches a counterattack to restore the battle area and destroy enemy forces in the area of penetration. The decision to counterattack is made by the battalion commander. In making his decison, he considers these questions:

1. Has the enemy been slowed or stopped forward of positions of the battalion reserve?
2. Have all available fires been employed without destroying the enemy?
3. Are reserves and supporting fires adequate to support the counterattack?
4. Has terrain been lost or threatened that jeopardizes the accomplishment of the mission?
5. Is a counterattack practical, in view of obstacles which may result from nuclear fires in the area?

Based on a consideration of the preceding questions, the battalion commander determines the probability of success. Affirmative answers to these questions generally favor a counterattack. However, they need not all be affirmative. An estimate is the decisive factor and a consideration of these questions is not a substitute for an estimate. As an example, if the defender is strongly supported and has an adequate reserve, the stopping or slowing of the enemy forward of reserve positions need not be the controlling factor in making a decision.

The counterattack capability is neither dissipated against minor enemy success nor employed against overwhelming odds. When it is launched, the counterattack is given all possible means to insure accomplishment of the mission. Piecemeal commitment of the counterattacking force jeopardizes the success of the entire operation. The counterattack is therefore carried out rapidly and aggressively, employing all the combat power necessary to insure success. After a successful counterattack, the battalion commander makes appropriate modifications to his defensive plan. If the counterattack fails to seize the objective, the ground gained is held until further orders are received or reinforcements are made available.

Barrier Planning

The battalion commander plans for use of obstacles forward of and within his defensive area. Care must be exercised in planning the barrier system to avoid interfering with the rapid shifting of units. They are constructed with due regard to the location of defensive positions and the effect of barriers on the mobility of friendly forces, particularly in the counterattack. Toxic chemical landmines can be integrated into or supplement the barrier system to strengthen obstacles and assist in denying areas. Exploding flame devices, flame expedients, and illuminants can be prepared, controlled and fired by forward elements to create obstacles. Natural obstacles are used to the maximum, since the demands on manpower, material, equipment, and time impose a limitation on the extent of barrier construction.

The purpose of obstacles is to deny the enemy easy approaches into the position, to keep him under flanking, flat-trajectory fire, and to canalize his attack into killing areas where the reserve can be used effectively. Barrier systems and minefields are the principal types of obstacles. Wire entanglements are laid out so their outer edges can be covered by flanking fire. Other obstacles are coordinated with demolitions. All obstacles are covered by fire to hinder their removal and breaching; they should be concealed, whenever possible, to increase their surprise effect on the enemy. Minefields are used to strengthen natural obstacles, cover likely avenues of enemy approach, and to protect exposed flanks. Barrier and denial plans are coordinated with adjacent units, and must conform with like plans of superior echelons.

Deception

In developing his plan of defense, the battalion commander considers the use of deception measures which may cause an attacker to dissipate or misdirect his effort. The security force employs deception to cause the enemy to deploy his forces prematurely and delay the execution of his plans. Dummy positions and equipment and simulated activities may enhance the economy of force and/or cause the enemy to execute unnecessary offensive action and render his force vulnerable to counteraction.

Dummy fortifications mislead the enemy and disperse his fire. Surprise may be achieved by substituting real weapons for dummies in positions which have been discovered by the enemy.

The Fire Plan

Throughout the development of the defensive scheme of maneuver, the battalion commander concurrently develops a plan of fire support. The purpose of fire support is maximum destruction of the enemy. This plan includes the support of security forces of the FEBA, and the reserve.

Final protective fires are planned forward of the battle area to break up the enemy assault. Final protective fires include direct fires and the allocated barrages of supporting artillery and those of organic mortars. The battalion commander employs barrages to cover dangerous avenues of approach into the battle area. He designates the general location of each barrage. The forward rifle company commander in whose area the barrage is located specifies its exact location on the ground to his forward observer and reports its exact location to the FSC (fire support coordinator). The rifle company commander assigns the location of a barrage(s) for the company mortars to cover approaches not covered by the barrages from battalion or to extend the coverage of these barrages.

The fire plan at any echelon consists of the coordination of fire available to that echelon with the fire plans of the subordinate echelons. Systematic flanking fire by front line automatic weapons, supplemented by the fires of available supporting arms, constitutes the basis for defensive dispositions. Thus, the fire plans of units

on the FEBA, are the basis of the entire fire plan.

The organic fire of any echelon is seldom as adequate as is desired. Deficiencies in fire are made up by support from the next higher echelon and/or available supporting weapons. In the defense, the barrier plan (including demolitions) location of defensive positions, counterattack plans, and the conduct of the defense are coordinated with the fire support plan to: anticipate the development of lucrative targets, exploit targets before they disperse, and expedite procedures to exploit fire support.

Communications

To control the defense, the commander must plan and insure adequate communications with higher, lower, adjacent, attached, and supporting units. All means, including radio, wire, messenger, visual, and sound, are used to the maximum extent practicable.

In the defense, wire is a principal means of communication. When adequate wire communication is available, radio is not used; however, radio nets remain open since wire communication may be interrupted or may be inadequate for the situation. Use of radio is normally restricted except during periods of enemy contact. Pyrotechnics and other visual signals may be used in the defense for identification of friendly units, to call for lifting and shifting supporting fires, and in the execution of counterattack plans.

Alternate Plans

The battalion commander plans for all foreseeable contingencies. He plans alternate and supplementary positions to insure flexibility in his defense plan. Flexibility is also obtained by maintaining a reserve and by centralizing the control of fire support at the battalion level. Counterattack plans are prepared with the knowledge that they frequently may have to be adjusted to meet a different set of circumstances than originally envisioned.

COUNTERATTACK PLANNING

Counterattack plans are prepared concurrently with plans for the defense. They are prepared for all likely enemy penetrations within the defensive area. At the battalion level, a counterattack is a limited objective attack designed to destroy the enemy within a penetration and to regain lost portions of the battle area. The battalion reserve normally provides the maneuvering force, but the counterattack plan provides for including other organic, supporting and attached elements. The maneuvering force is supported by the weapons of the battalion, including where practicable, weapons of the forward companies. Normally, a single coordinated effort is delivered, as the situation and terrain dictate, avoiding passage through friendly troops to the extent practicable. All friendly elements within the penetration are attached to the commander of the maneuvering force.

The battalion commander prepares counterattack plans and gives priority to those plans which assume the loss of or threat to the most critical terrain. The detailed planning for the counterattack is often accomplished by the commander of the reserve unit(s). Plans are rehearsed as time and security permit. Every effort is made to insure reconnaissance and rehearsal by key participating personnel. Night rehearsals are conducted as required.

A counterattack plan has the usual features of any attack plan. Special consideration is given to the following;

1. The visualized enemy penetration. The commander must make assumptions as to the size of the force in the penetration, its width and depth, and the capabilities of the friendly forces to block and eliminate the penetration.
2. Objective. The objective assigned to the maneuver force is usually a terrain feature within the penetration the seizure of which is essential to the elimination of the penetration and the restoration of the battle area.
3. Direction of attack. A direction of attack is assigned which will permit unity of effort and provide necessary close control of the attacking forces. Normally, the attack is directed at the flank or base of the penetration and avoids friendly defense areas.
4. Line of departure. A line of departure is designated. Its location may be modified later to suit the situation at the time of execution.
5. Time of attack. Consideration must be given to the time required to deliver fires in support of the counterattack, and to move the counterattacking force to the line of departure.
6. Attack position. This position is designated but not used unless essential for the conduct of the attack, since unnecessary massing of troops and delay may result.

PREPARATIONS FOR THE DEFENSE

While the commander and staff are preparing the plan of defense, concurrent actions are being taken within the battalion to prepare the unit for its defensive mission.

When defending units arrive on position, they immediately begin organization of the defensive position. Many of the tasks involved are carried on concurrently, but some may require priority. The battalion commander may specify the sequence for the preparation of the position and any special precautions to be taken regarding camouflage. The following is a recommended sequence:

1. Establishing security.

2. Positioning weapons.

3. Clearing fields of fire, removing objects making observation, and determining ranges to probable target locations.

4. Providing signal communication and observation systems.

5. Laying minefields and preparing important demolitions.

6. Preparing weapon emplacements and individual positions, to include overhead cover, and camouflaging them concurrently.

7. Preparing obstacles (other than minefields) and less vital demolitions.

8. Preparing routes for movement and for supply and evacuation.

9. Preparing alternate and supplementary positions.

10. Preparing NBC protective shelters as required.

11. Preparing deceptive installations in accordance with deception plans of higher headquarters.

The organization of the ground begins as soon as the troops arrive in the area and continues as long as the position is occupied. When it must be organized while the force is in close contact with the enemy, defense against attack may be required during any or all stages of the organization. Maximum use is made of available fires to cover the organization, and smoke may be used to deny the enemy observation of the preparation.

TYPES OF POSITIONS

Positions classified according to mission are PRIMARY, ALTERNATE, and SUPPLEMENTARY positions. The primary firing position assigned to a unit or individual weapon is the one from which the most important mission can best be accomplished. An alternate position is one assigned in the event that the primary position becomes untenable. A supplementary position is one from which targets can be fired upon which cannot be engaged from the primary or alternate positions.

Positions classified according to ground are FORWARD SLOPE, REVERSE SLOPE, and COUNTERSLOPE positions. Forward slope positions are located on forward, or toward-the-enemy, slopes; they usually afford the best observations and fields of fire. Reverse slope positions are located on reverse, or away-from-the-enemy slopes; they usually offer the best cover and concealment. Such a position should be located not more than 500 yd (about the maximum effective rifle range) nor less than 100 yd from the crest.

A counterslope position is a position located on the forward slope of the next elevation to the rear, and is used in conjunction with a reverse slope defense. (See fig. 2-22.) Such a position is normally used by the reserve of a unit manning the forward reverse slope position.

Selection of Positions

The first criterion in the selection of a position is whether the mission can be accomplished and future operations facilitated. This may require the defense to be set up on terrain

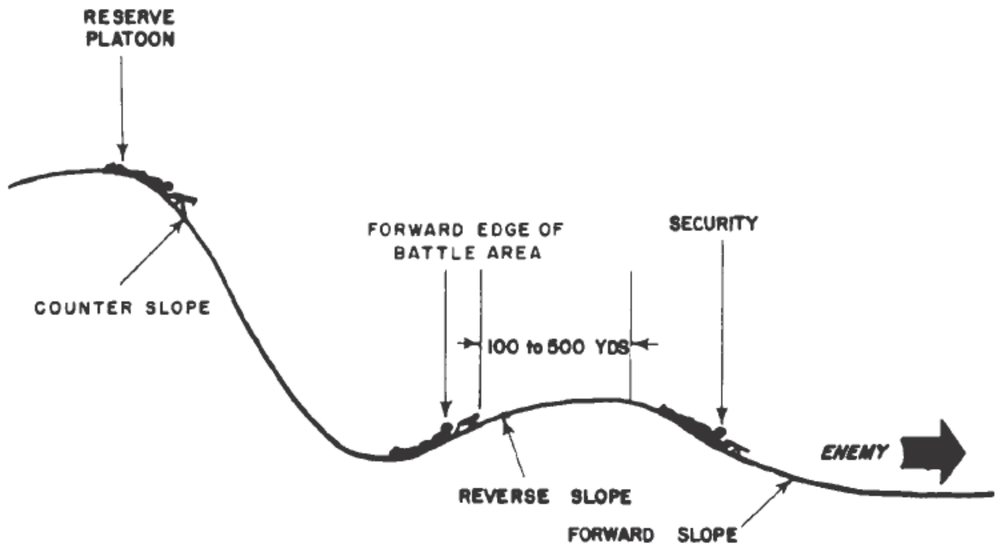

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Figure 2-22.—Defense of a reverse slope.

which does not best suit the composition and capabilities of the defender. Seldom will a position be found which satisfies all requirements. The position, and the force within it, must be one that the enemy must attack—that is, one which he cannot bypass without serious threat to his flank or rear.

Within the limitations of the mission, a position is selected which increases the defender's capabilities and decreases those of the enemy. Thus a defender with a relatively heavy armored capability will choose a position where armor can be utilized, and one opposed by an enemy with heavier armored capability will choose terrain suited for a good defense against armor.

The defending commander seeks terrain with maximum natural defense strength. He selects positions which give him control or possession of as many as possible of the following terrain factors:

1. Critical terrain
2. Avenues of approach
3. Observation and fields of fire over enemy avenues of approach
4. Natural obstacles which will impede the enemy's advance
5. Cover and concealment

Of these factors, the most important are observation and fields of fire.

ORGANIZATION OF THE DEFENSE

Organization of the defense consists of three integrated efforts: organization of the GROUND, organization of FIRES, and TACTICAL organization.

Organization of the Ground

In organization of the ground, measures for increasing the effectiveness of fire take precedence over field fortifications. Therefore, fields of fire are cleared as the first step—that is, the areas which will be fired over are determined, and any obstacles located therein are removed. After this has been done, the construction and improvement of individual cover, defensive works and obstacles, and routes of approach for supplies and reserves are planned.

Field Fortifications

The construction of field fortifications is limited only by the time and means available. Troops and weapons should have the best possible protection. Field fortifications are located to cover all avenues of enemy approach. They may be protected by barbed wire. Adequate drainage must be considered in stabilized situations. Overhead cover is provided by means of dugouts, or by means of concrete, log, dirt, or steel shelters, depending on the means and

material available. Alternate and supplementary positions are prepared in accordance with an established system of priority. Construction of works should never cease; the improvement of a position should continue as long as the position is occupied.

Communication Routes

Routes of communication throughout the position are also continuously improved, to facilitate movement of supplies and personnel. They are also built where necessary to ease the functions of observation and command. Communication trenches must be located, insofar as possible, where they are concealed from the enemy and do not disclose the positions of combat emplacements.

CONDUCT OF THE DEFENSE

In conducting the defense, the commander maintains the integrity of the battle position by an aggressive combination of fire, fighting in place, and counterattacking.

Sequence of Defensive Action

In the initial stages, particular importance is focused on intelligence. The probable strength, composition, direction, and time of enemy attack must be known. Aggressive reconnaissance and observation, both by ground and air (if available), is therefore essential. Good reconnaissance permits the defender to maintain the maximum degree of initiative.

In order to maintain continuity in the defense or to retain a sufficient reserve for a later decisive action, it may be desirable to withdraw on a portion of the front. Such action requires personal leadership by all commanders concerned, careful prior planning, and well trained troops. A unit entrusted with the defense of a tactical locality, however, never abandons it unless ordered to do so by higher authority.

The defender, at every echelon, must take advantage of each opportunity to regain the initiative. Such an opportunity frequently occurs when an enemy attack is repulsed, or after he has seized an objective but is not yet organized to defend it, or when he is already closely engaged elsewhere.

THE RIFLE PLATOON IN DEFENSE

Area Dispositions

The battalion commander assigns defense areas to his forward rifle companies. The company commanders, in turn, assign defense areas to their forward rifle platoons.

FRONTAGES.—The frontage assigned a rifle platoon on the FEBA (in open terrain with good fields of fire) should not exceed 600 yd. In wooded or brush covered terrain where fields of fire are poor, the frontage assigned should not exceed 300 yd. A critical terrain feature or avenue of approach into the company defense area should be covered by one unit. The assigned area of a platoon should definitely include responsibility for at least one of the above mentioned features.

DEPTH.—The depth of the platoon defense area may extend from 50 to 200 yd. All of this cannot be physically occupied by troops; therefore, only the most critical portions are assigned as positions for squads. The remainder is defended by fire. A forward rifle platoon defense area is shown in figure 2-23.

MACHINE GUNS.—Machine gun and other supporting weapons sections will normally be placed within a platoon defense area to carry out fire missions assigned by the company commander. Because it is the rifleman's responsibility to protect such weapons, such emplacements will influence the rifle platoon's defensive organization to a great extent.

SELECTIONS OF POSITIONS.—The company commander will indicate the general positions to be occupied by the forward rifle platoons. These positions will include portions of the FEBA indicated by battalion. For instance, the company commander might order a platoon to occupy the forward slope of a hill within the platoon defense area, across which the FEBA runs.

Within the area designated by the company commander, the platoon commander selects the most tactically sound positions for his squads. The platoon commander's positioning of his squads determines the exact trace of the FEBA. His choice must agree as nearly as possible to the FEBA designated by the company commander. For instance, if the company commander indicated the forward slope of a hill, the platoon commander may not set up his defense on the reverse slope.

In selecting his squad positions the platoon commander will be concerned primarily with his mission—with the support of other units, to stop

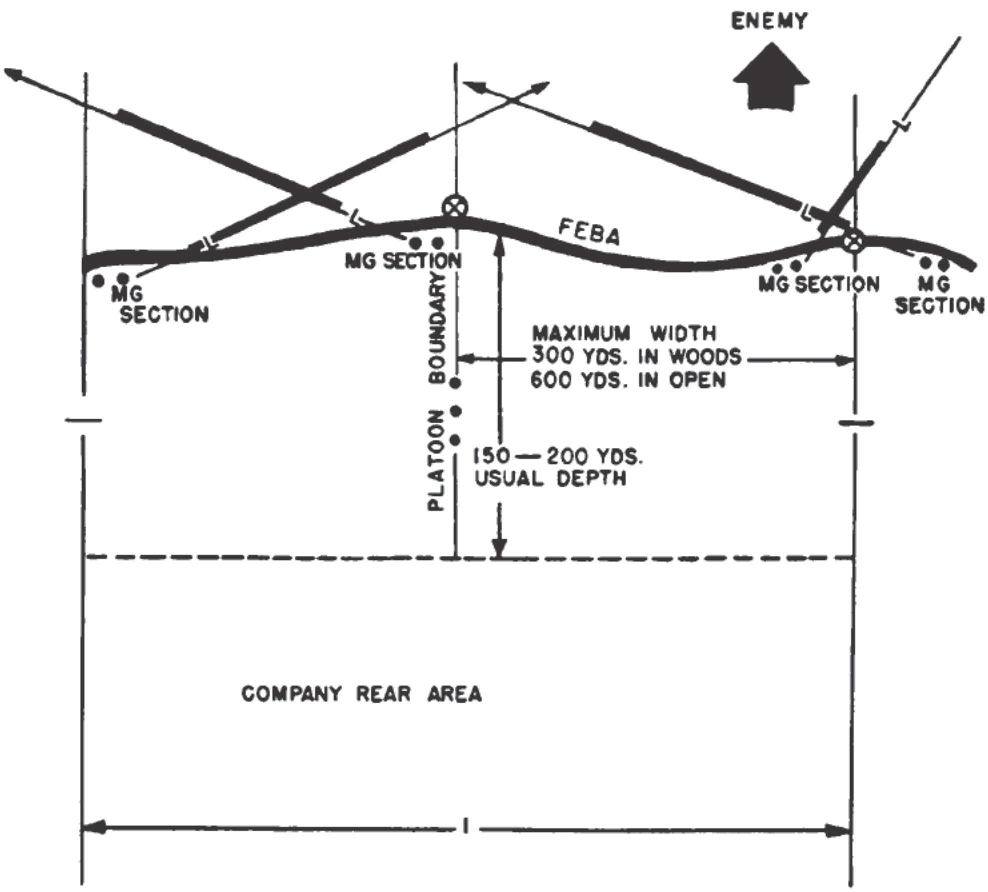

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Figure 2-23.—Forward rifle platoon defense area.

the enemy by fire in front of the FEBA, and to repel him by close combat if he reaches it. The enemy situation, friendly situation, and nature of the terrain have been considered by higher commanders before the platoon commander is ordered into position. He, however, must also evaluate the five terrain factors in arriving at his decision: critical terrain features, avenues of approach, observation and fields of fire, obstacles, and cover and concealment. Through proper evaluation he arrives at a decison which will place his squads in the strongest positions from which they can carry out the platoon's mission.

Troop Leading Steps

In a fast-moving situation the troop leading steps which you learned at second or third-class level may be curtailed for lack of time. They will, though, be used insofar as time allows. The platoon commander will usually receive the defense order, along with the other company officers, at the company vantage point. He should not, however, be called back from his platoon if he is in contact with the enemy. After he receives the order, he will then commence the troop leading steps.

Organization of the Defense

DISTRIBUTION OF SQUADS.—The rifle platoon will usually best accomplish its mission with three squads generally abreast, facing the expected direction of attack. This enables the platoon to readily place all its fire power at once in front of the FEBA. A squad is not kept in reserve for the missions normally assigned to a reserve unit. Such missions (addition of position depth, limiting penetration, protecting flanks and

rear, and local counterattacking) usually require a unit with more combat power than a squad has. The platoon with three squads abreast is able to cover its front and the intervals on its flanks, and also mutually support adjacent platoons.

When the platoon is filling a narrow gap between adjacent flank platoons, it is possible to place the squads abreast without echeloning the flank squads rearward. (See A, fig. 2-24.) If the gap is wide, however, the flank squads must be bent back to gain mutual support between platoons. (See B, fig. 2-24.)

Each squad is assigned a sector of fire which overlaps that of adjacent squads (including, for flank squads, the squads of adjacent platoons).

When only two squads are required to cover the platoon front by fire, and a suitable depth position for the third squad exists, then one squad may be placed in depth position; this squad must, however, be able to bring its fire to bear forward of the FEBA. (See C, fig. 2-24.)

SUPPLEMENTARY POSITIONS.—A rifle platoon must be able to defend its area against attack from any direction. Squad supplementary positions which allow the squad to fire to the flanks and rear are therefore prepared. These positions should be located as close to the primary positions as the terrain permits. (See A and B, fig. 2-24.) the depth of the platoon area is determined by the depth interval between primary and supplementary positions; this is

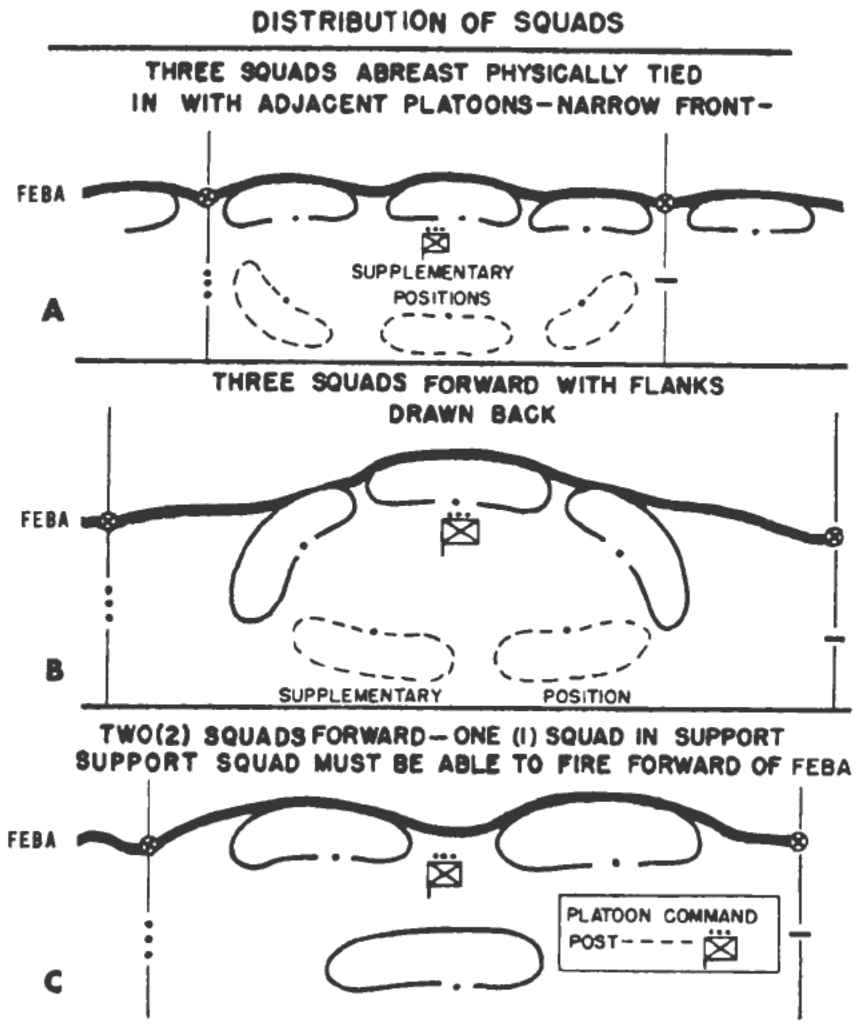

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Figure 2-24.—Platoon defense formations.

normally 200 yd or less. In open, flat terrain riflemen can shift their fire to the rear without changing position—in such a case, supplementary positions are unnecessary. This is a desireable situation, because a change of position during a fire fight is always dangerous. Therefore, supplementary positions are used only when their use is unavoidable. Natural cover, drainage ditches and other covered routes should be used in moving to supplementary positions. If time permits, communication trenches should be prepared.

PLATOON OBSERVATION/COMMAND POST.—The platoon commander establishes an observation/command post from which he can observe as much as possible of the platoon sector in front of the FEBA. The position should be dug in, camouflaged, and provided with covered and concealed routes of approach from the rear.

The platoon commander keeps two runners at his OP/CP and sends one to the company command post. Quite often the terrain does not allow a post from which the entire area can be observed and controlled. In this case the platoon CPO establishes a supplementary position from which he can control part of the platoon. The platoon commander is not, of course, relieved of his responsibility for the entire platoon; he is merely aided in his observation and control.

In addition to the OP/CP, the platoon commander also chooses a covered and concealed position for a supply point. Supplies are brought to and casualties evacuated from this position under the direction of the platoon guide.

SECURITY.—The platoon commander provides local security for his position. The company commander will normally direct that outguards be established forward of the FEBA. If no company security is provided or ordered, the platoon commander must establish his own. Outguards should be of fire team strength or less, and are usually placed within 400 yd of the FEBA. Certain individuals must also be kept continuously alert to observe for enemy ground and air action.

SQUAD SECTORS OF FIRE.—The platoon commander develops a fire plan for his platoon. The plan must cover by fire the entire platoon front immediately forward of the FEBA. This is accomplished by assigning overlapping sectors of fire to his squads, and sectors and primary directions of fire to his machine gun as shown in figure 2-25. The sectors of a flank squad must include the interval between the platoon's flank and that of an adjacent platoon.

MUTUAL SUPPORT.—The platoon's fire should also cover, to the fullest extent possible, the fronts of adjacent platoons. This is a factor in mutual support. The platoon commander ensures that his fire will intersect that of adjacent platoons forward of both platoon flanks.

AVENUES OF APPROACH.—Enemy infantry avenues of approach must be covered by fire—preferably machine gun fire. Such avenues include ditches, gullies, wooded draws, and any other covered and/or concealed approaches.

SUPPORTING WEAPONS.—In organizing his fire, the platoon commander ensures that all supporting weapons in his area are protected by the fire of his riflemen and machine gunners.

ORGANIZATION OF THE GROUND.—The platoon will organize the ground according to the priority established by the company commander. The normal platoon tasks are digging foxholes, clearing fields of fire, constructing tactical and protective wire, placing antipersonnel mines, constructing obstacles, and camouflage. When time permits, the platoon may dig communication trenches.

Conduct of the Defense

INITIAL CONTACT.—The first direct contact between a platoon on the FEBA and enemy ground forces occurs when the attacking enemy appears within 500 yd of the platoon position. The outposts will normally warn the platoon of the enemy's approach. The platoon commander notifies the company commander of the presence of the enemy, their direction of advance, armament, strength, and any other pertinent information.

As the enemy advances into the zone of the final protective fires, the company or battalion commander (if the platoon commander has not been authorized to do so) will order such fires into effect. When he has not been authorized to call down final protective fires, the platoon commander must keep the company commander advised on the development of the enemy attack. This aids the company commander in making

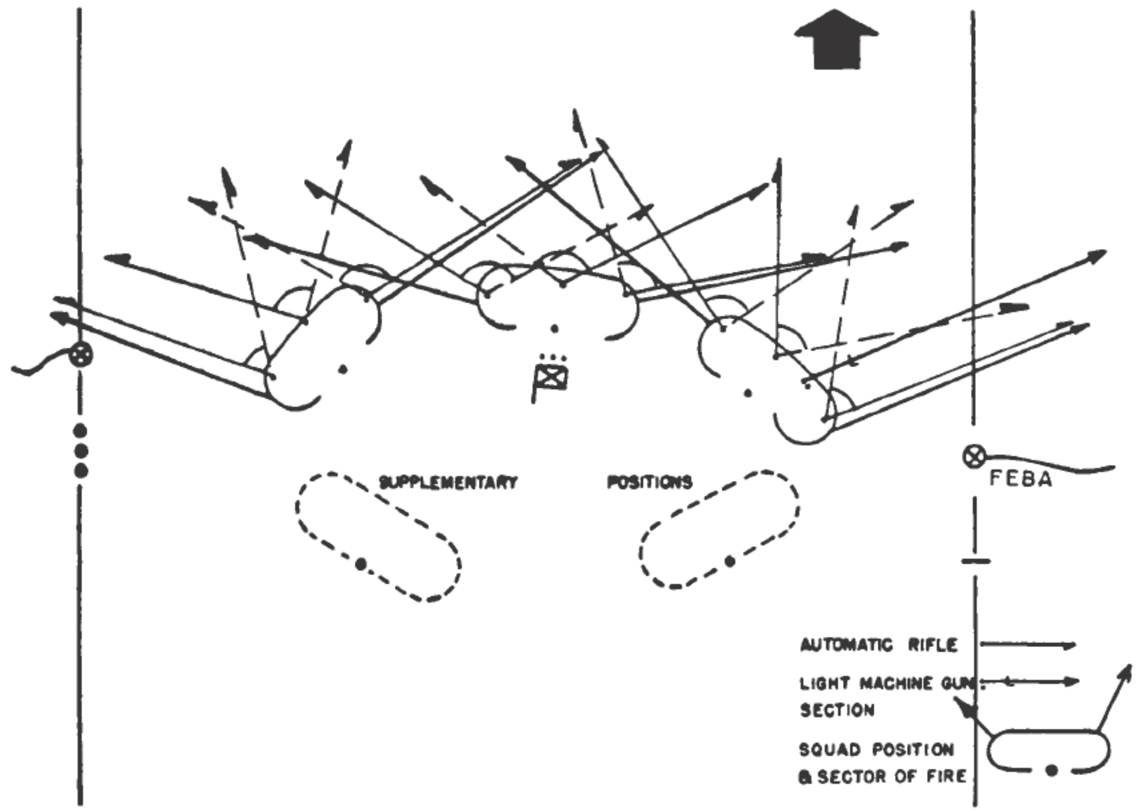

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Figure 2-25.—Platoon defensive fire plan.

his decision as to when to call down final protective fires. Because it discloses the entire FEBA, the final protective fire must not be brought to bear until the last possible minute, and only when absolutely necessary. When the order (usually a signal flare) is given, the platoon commander makes sure his squads are covering their assigned sectors of fire, that machine guns are firing their principal directions of fire, and that in general, the platoon fire plan is being carried out.

CLOSE COMBAT.—If the enemy succeeds in breaking through the final protective fire and reaches the FEBA, every man remains in his position and engages the enemy in close combat, using grenades, point blank fire, and bayonets. Machine gunners may use a "free gun" during this part of the defense if they find it to their advantage. Enemy tanks are met with rifle grenades and other available means. The battle position is held at all costs.

PENETRATION IN ADJACENT AREAS.—Because of the heavy volume of fire which falls on a platoon position during an enemy attack, movement within a platoon position is often impractical. However, if the enemy penetrates the areas of adjacent or supporting platoons, the platoon commander must move some of his men to previously prepared supplementary positions to protect his exposed flanks or rear.

INFORMATION TO COMPANY COMMANDER.—The platoon commander takes full advantage of the fire support and other help available from company and battalion by constant communication with the company commander. He continually keeps him informed about the progress of the enemy attack.

Reserve Platoon

The company commander usually places two rifle platoons on the FEBA and the third in a depth position. The position for the reserve platoon should be at least 150 yd from the nearest elements of the forward platoons, but no more than 500 yd from the FEBA as

shown in figure 2-26. In this situation the reserve platoon is outside the zone of enemy fire falling on the FEBA, but within effective small arms range. The reserve platoon is responsible for all the company defense area not included in the areas of the forward platoons. The position selected may be a key terrain feature from which the reserve platoon can carry out its mission; or the platoon may be split, with squads separately defending particular terrain features or blocking individual avenues of approach.

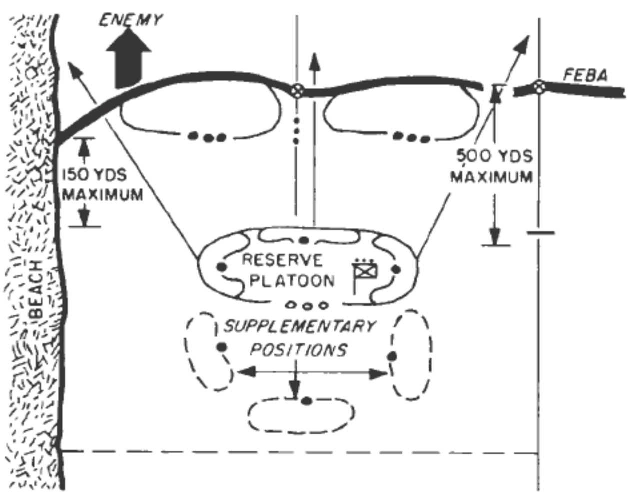

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Figure 2-26.—Reserve platoon in defense.

THE WEAPONS PLATOON IN DEFENSIVE COMBAT

Machine guns are the backbone of the defense. Their fire, coordinated with that of other weapons, is employed to stop the enemy regardless of the direction of his attack. The following characteristics, unique with the machine gun, are the basis of its value as a defensive weapon:

1. Large volume of fire which can be readily applied.
2. The suitability for enfilade fire because of its long, narrow beaten zone.
3. The ease of concealing the weapon.
4. The fixed mount which enables effective fire during periods of restricted visibility.

The machine gun section is a fire unit under normal circumstances. Regardless of the nature of the mission, two guns (one section) are usually assigned the same mission. When certain conditions prevail, however, machine gun sections may be split. Such conditions would include an overly extended front, poor fields of fire, and guns placed in depth (as with reserve units).

Missions

Machine guns employed throughout the defensive position normally have one or more of the following missions:

FINAL PROTECTIVE LINE.—Insofar as possible, the machine guns of front line companies will be situated where they can fire interlocking bands of grazing fire across the front of the company. These guns provide a major portion of the final protective fires.

Guns assigned a final protective line mission may also be assigned a sector of fire if the location of the firing position makes the assignment of a sector practicable.

CLOSE SUPPORT OF THE FEBA.—Machine guns with this mission actually have two missions; covering possible avenues of enemy approach, and limiting penetrations. Adequate final protective line fires have priority over such missions however.

When practical, some of the machine guns of a front line company are placed in rear of the FEBA to cover probable avenues of enemy approach into the position. Such guns must be within the company defense area.

Machine guns assigned the close support mission should also have previously prepared supplementary positions from which they can check by fire limited penetrations in the FEBA.

PROVIDE DEPTH TO THE DEFENSIVE POSITION.—Some machine guns of the reserve company are placed in depth within the battalion defense area to check deep penetrations by fire.

REINFORCE COMBAT OUTPOSTS.—Reserve company machine guns are sometimes placed with units in the outpost system.

PROTECT FLANKS AND REAR.—Protection of the flanks and rear is a particularly important mission when there is an open flank. Machine guns in close support of the FEBA and those placed in depth to check deep penetrations will normally be assigned supplementary positions from which they can accomplish this mission.

SUPPORT COUNTERATTACKS.—In the event a penetration is effected by the enemy, the machine guns of the reserve company are

the principal source of close support for that company's counterattack. After the counterattack, these guns are used to restore the fire plan in the penetrated area.

Selection of Positions

The primary consideration in the selection of firing positions for machine gun sections is the accomplishment of the mission. However, other factors must also be considered. Cover and concealment of the gun and crew are essential if the gun is to remain in action, automatic weapons being the primary target of enemy infantry. Intelligent use of nature terrain irregularities will reduce the labor and time necessary for construction of emplacements.

Routes of ammunition supply to the gun positions should be given consideration. An initial supply will seldom cause a problem in a defensive situation. However, covered routes of approach to gun positions will be necessary after the initial supply is consumed.

Fields of fire will have to be cleared in most cases. Only enough foliage to allow unobstructed fields of fire should be cut. The clearing of all foliage will unnecessarily reveal the gun position to the enemy.

When a section is emplaced, the two guns should be at least 30 yards apart to reduce the effectiveness of hostile mortar and artillery fire.

PLACEMENT OF GUNS.—The result of the placement of the machine guns shown in figure 2-27 is the ability of at least one section to engage any enemy counterattack. If necessary, the company commander improves the machine gun fire plan by the selection of new positions. This, and the assignment of final protective lines, is carried out as soon as practicable so the flanks and entire company front will be covered by interlocking bands of grazing fire.

Figures 2-27 and 2-28 illustrate sound and effective principles for employing machine guns in defense. The result of coordinating machine gun fire plans only within the company, however, may result in weak points at the company boundaries. This probable defect is remedied as quickly as possible by the battalion commander. The result of his coordination is the battalion machine gun fire plan, and is the first real coordination achieved. Other troop dispositions are vitally affected by the battalion plan. Until this coordination is effected, company commanders are primarily concerned with protection of only their own companies and areas.

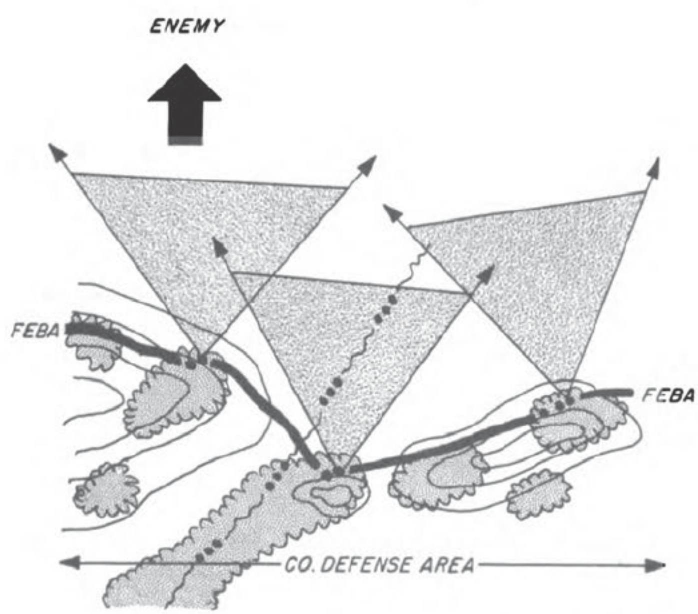

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Figure 2-27.—First location of company machine guns

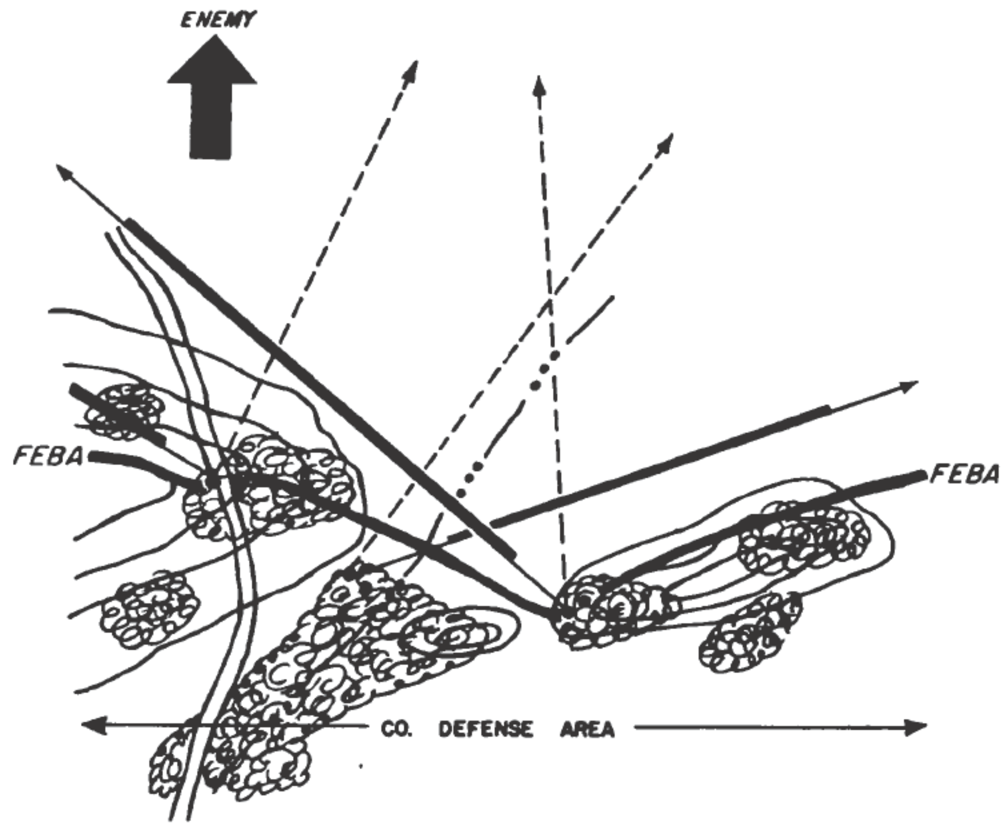

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Figure 2-28.—Coordinated machine gun fire plan covering company front with interlocking bands of grazing fire.

The machine gun platoon of the reserve company is employed in a manner consistent with the anticipated mission of that company. When the battalion fire plan is in effect, the transition to the defense has been completed and the continuous improvement of positions begins.

STRENGTHENING THE POSITION.—The strengthening or improving of a position into as formidable a defense as the time allows should be the goal of each unit leader. The primary limiting factors in strengthening or improving a position are:

Time available for reconnaissance by commanders.

A well coordinated battalion fire plan. Fire must be exchanged across company boundaries to eliminate the possibility of weak points in the defense.

The extent of digging-in and camouflage. This is limited only by the time an organization spends on a position.

The battalion fire plan (fig. 2-29) is characterized by a system of interlocking bands of grazing fire and a mutual exchange of fires across company boundaries. Figure 2-23 shows a portion of the guns of the front line companies in support of the FEBA. They are covering possible avenues of enemy approach into the position. The machine guns of the reserve company are placed in depth within the battalion defensive area. They are prepared to check deep penetrations. Guns in close support of the FEBA and in depth should all have alternate and supplementary as well as primary positions.

The responsibility for selecting general firing positions and assigning missions in a mobile construction battalion is that of the

company commander. The defense information necessary to the company commanders is normally communicated to them in a battalion defense order. Having received the order, the company commander makes a reconnaissance and coordinates the disposition of the rifle platoons with that of the machine guns. He then issues the company defense order. This order must include the following information:

Primary firing positions.

Direction of the final protective lines.

Sectors of fire.

Elements of fire control.

Organization of the ground to include clearing fields of fire, construction of emplacements, cover for personnel, and priority of work.

The weapons platoon commander should prepare an overlay of his fire plan as soon as possible. It must show firing positions, final protective lines to include any gaps or dead space, and sectors of fire. This overlay is submitted to the company commander as an aid in coordinating the rest of his fire.

Machine gun ammunition carriers are used to augment the fire of the unit. However, their fire is not included in the prepared fire plan.

Tactical wire is placed inside final protective lines so it will slow up an approaching enemy in the areas covered by the grazing fire of machine guns. The actual emplacement is usually a function of the rifle platoons, but the weapons platoon commander must check to ensure it is properly placed.

Protective wire is placed around gun positions to prevent the enemy from coming within hand grenade range.

Fire Control

Fire control includes all operations connected with preparation and actual application of fire on a target. It ensures a leader the ability to open fire the instant he desires, adjust the fire of his guns, regulate the rate of fire, shift from one target to another, and to cease firing.

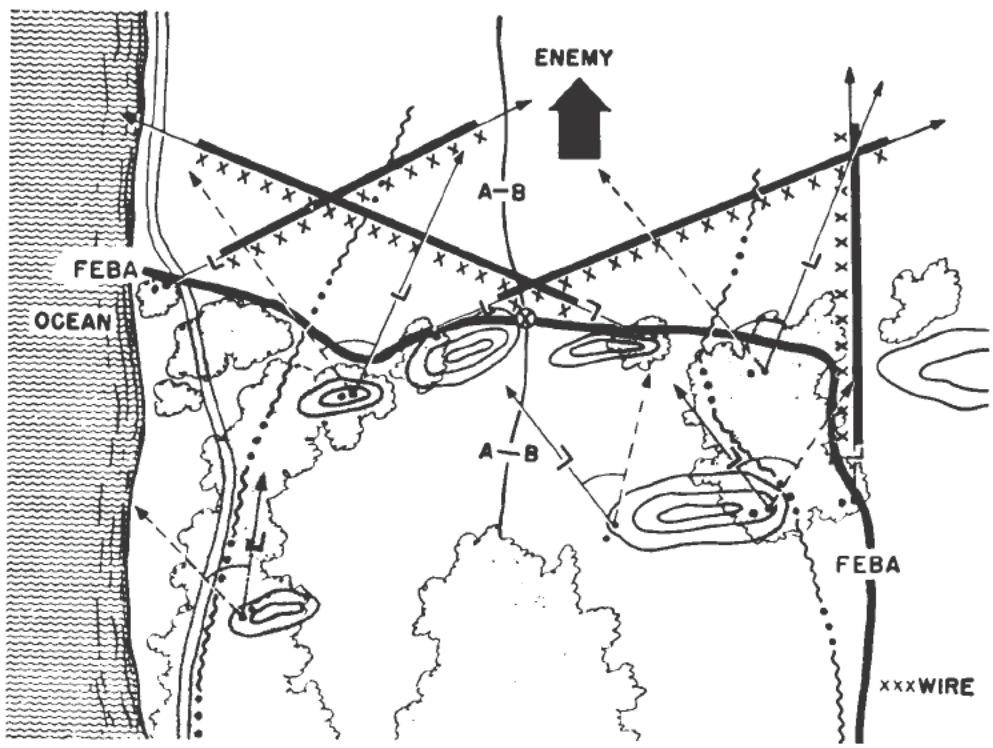

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Figure 2-29.—Battalion machine gun fire plan.

The ability of a leader to exercise proper fire control depends primarily on the discipline and technical training of the gun crews. Failure in this respect results in danger to friendly troops, loss of surprise effect, premature disclosure of positions, firing on unimportant targets, loss of time in adjusting fire, and wasted ammunition.

The weapons platoon commander must coordinate with the rifle platoons to ensure his machine guns' fire will not be masked by rifle units and vice versa. Arrangements must also be made to afford rifle protection for machine gun emplacements.

The distance between machine gun sections in the defense requires detailed fire control instructions to the sections before a battle begins. Once firing has started, control by the leader is limited to arm and hand signals, personal contact with subordinates through whatever connecting trenches or covered approaches exist, and prearranged signals (pyrotechnics).

Final protective line fires are usually called down by company or battalion commanders. Platoon commanders may, however, be authorized to do so. The battalion commander, in his defense order, will designate the signal (usually a pyrotechnic) for each company. On this signal, machine guns begin firing on the final protective lines. Only guns which protect the unit whose signal has been given will fire.

The rate and duration of fires is normally specified in the unit defense order. The usual rate of section fire on final protective lines is rapid for 2 minutes (150 rounds per minute) followed by medium (75 rounds per minute) fire until ordered to cease. Section fire is maintained by two guns, firing alternate bursts. However, if, that action to his immediate front does not warrant a heavy volume of fire, he may adjust the rate to conserve ammunition.

Dead space and gaps will exist in final protective lines unless the defensive position is on perfectly level ground. These spaces must be covered by other weapons organic to or on call by the infantry unit.

Guns in close support of the FEBA open fire on targets of opportunity on the initiative of the section leader. Guns on final protective lines should not if such fire will allow them to be prematurely spotted and hence destroyed. The maximum range at which targets should be engaged by direct methods is 500 yards. Close support guns will open fire on all targets of opportunity, depending on cover, concealment, and frequent moves to alternate positions for protection from hostile fires.

Movements to supplementary positions will be made on the order of the platoon commander. He should have received instructions from the company or battalion commander. However, in extreme emergencies, the section leader may effect such a move on his own initiative if he spots a flank attack or penetration which may endanger the defensive area and cannot contact the platoon commander immediately.

Movement of guns to alternate positions will usually be made on the initiative of section leaders. They can most accurately judge when it is necessary.

Disabled guns are replaced from rear to front; that is final protective line guns are replaced by guns in close support of the FEBA, which are, in turn, replaced by guns originally placed in reserve.

COMPANY COMBAT

Immediately upon assuming the defense, the company commander usually goes to a designated central location in the battalion defense area to receive the battalion commander's defense order. He should not, however, be ordered from his troops if his company is in contact with the enemy. His company may be waiting in an assembly area to the rear, moving up, or already in the company defense area.

The troop leading steps of the company commander are the same as those described for a platoon commander.

Company Fire Plan

The company fire plan includes the fires of all company weapons. After the missions and locations of the heavy weapons have been assigned by the company commander, the company plan is formulated. It is built around and integrated with the plan for heavy weapons, both on the FEBA and in depth.

Boundaries are established to completely include company-sized tactical localities, such as hills, woods, draws, or any other key features or concealed and covered approaches into the battalion defense area. Responsibility for such areas must never be split between two commanders.

When the enemy has advanced to 500 yd from the FEBA, the company commander directs his riflemen and machine gunners to fire on targets of opportunity. However, guns zeroed on the final protective line should not fire at this time.

Supply

An additional problem of the company commander is that of supply and evacuation. Preliminary planning must include enough on-position ammunition, food, water, and other necessities to see the company through any sort of attack within the enemy's capabilities. Resupply and evacuation plans, made before the enemy attacks, will save the commander a great deal of effort at a time when tactical direction is requiring most of his attention.

CHAPTER 3

ELECTRICAL SKETCHING AND PLANNING

Blueprints, schematics, wiring diagrams, drawings, and plans are familiar to you by now. But did you ever stop to realize the important part they play in your work as a Construction Electrician? Wiring a building, installing equipment, and locating troubles are all simplified through the use of electrical drawings.

Take a look at figure 3-1. How long do you think it would take to wire that switchboard if an electrician had to stop and figure out each connection separately? Probably about 6 months. But with the aid of a drawing it could be finished in a few days.

Most first and second class CEs have had some experience working with drawings. But, if you haven't had the opportunity to work with the many types of drawings, this chapter will give you a glimpse of the application and importance of each drawing in electrical construction, and how to sketch and lay out a drawing using the proper symbols.

There are two Navy Training Courses listed in Training Publications for Advancement in Rating, NavPers 10052 that you should be familiar with; Construction Electrician 3 & 2, NavPers 10636-E, and Blueprint Reading and Sketching, NavPers 10077-B. If you have properly studied chapters 1, 6 and 9 of the latter and chapter 3 of the former, you should be familiar with the basic sketching techniques. You should also be familiar with the various types of drawings such as orthographic, isometric, perspective, and so on; and parts of drawings, such as symbols, title block, bill of material, notes, legends, details, and cross sections.

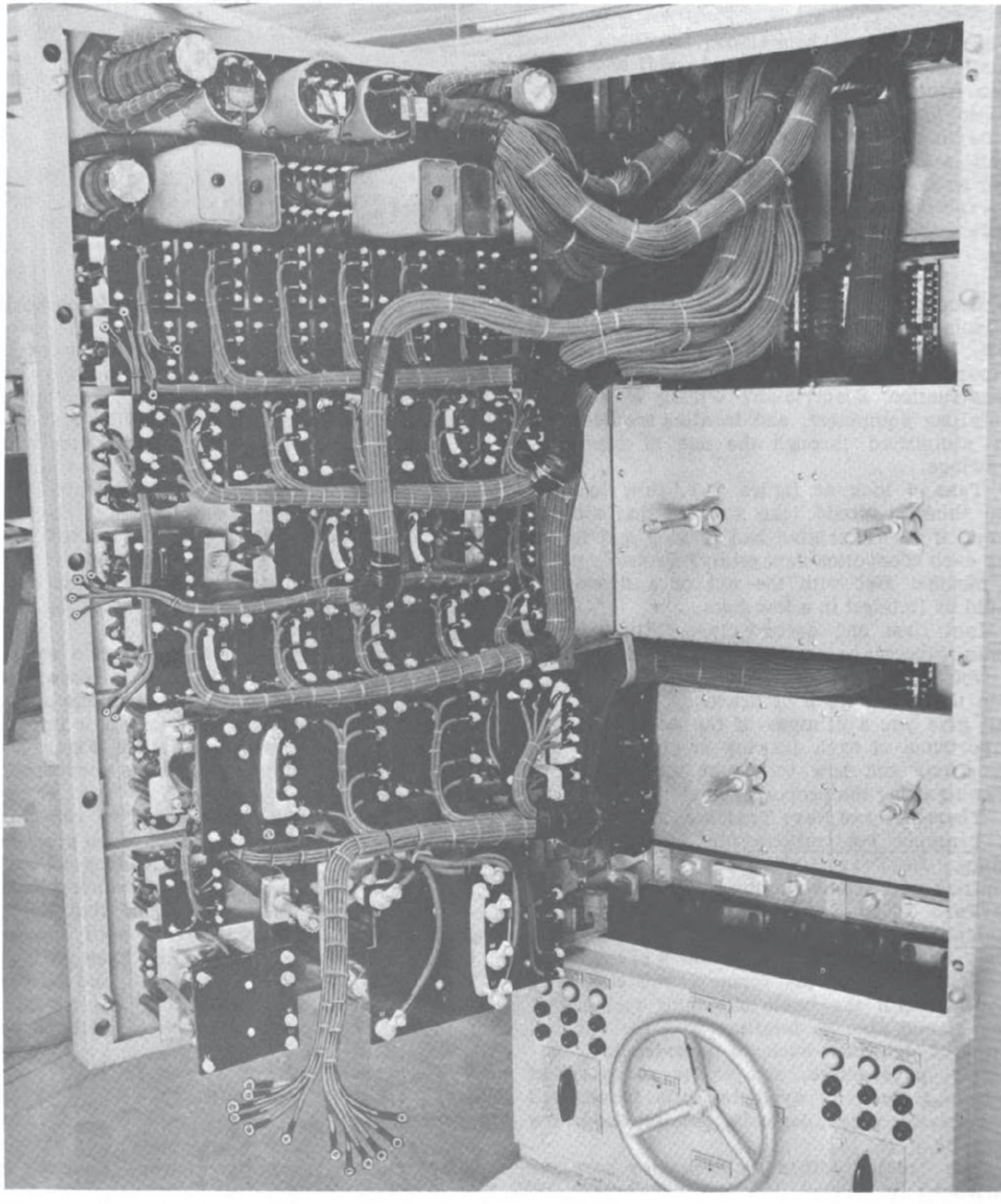
The major difficulty you may have experienced in trying to read prints may be summed up in one fact—your unfamiliarity with the symbols and abbreviations used. This is understandable, however, for there are several thousand symbols. To make the situation worse draftsmen have not always used the same symbols or abbreviations to represent certain items. Fortunately, however, the armed services have standardized the use of these symbols and abbreviations. To eliminate discrepancies, a Military Standard for Electrical and Electronic Symbols, MIL-STD-15-3, Abbreviations for Use on Drawings, MIL-STD-12A, Electrical and Electronics Reference Designations, MIL-STD-16B and Abbreviations (for Electrical and Electronics Use) MIL-STD-103, have been issued. These publications list the proper electrical symbols and abbreviations to be used on all military drawings.

Always try to picture the item a symbol is representing. Then, as you trace each circuit, you will begin to visualize the proper location of the various pieces and their importance to the complete installation. Figure 3-2 illustrates each item opposite its corresponding symbol.

The best way to learn how to recognize symbols and abbreviations is through practice. Avail yourself of every opportunity to study the prints of the installation to which you are assigned. Trace the circuits and find out the meaning of each unfamiliar symbol and abbreviation that you encounter. Then go back, when the installation is completed, and compare the finished job with the prints. All the lines, abbreviations, notes, and symbols will fit into a definite pattern.

SKETCHING

Sketching is a freehand method of drawing shape, size, and/or location of objects, and is a convenient and important means of communication. Objects or views can normally be drawn more quickly freehand than with instruments.



26.176

Figure 3-1.—Connecting a panel.

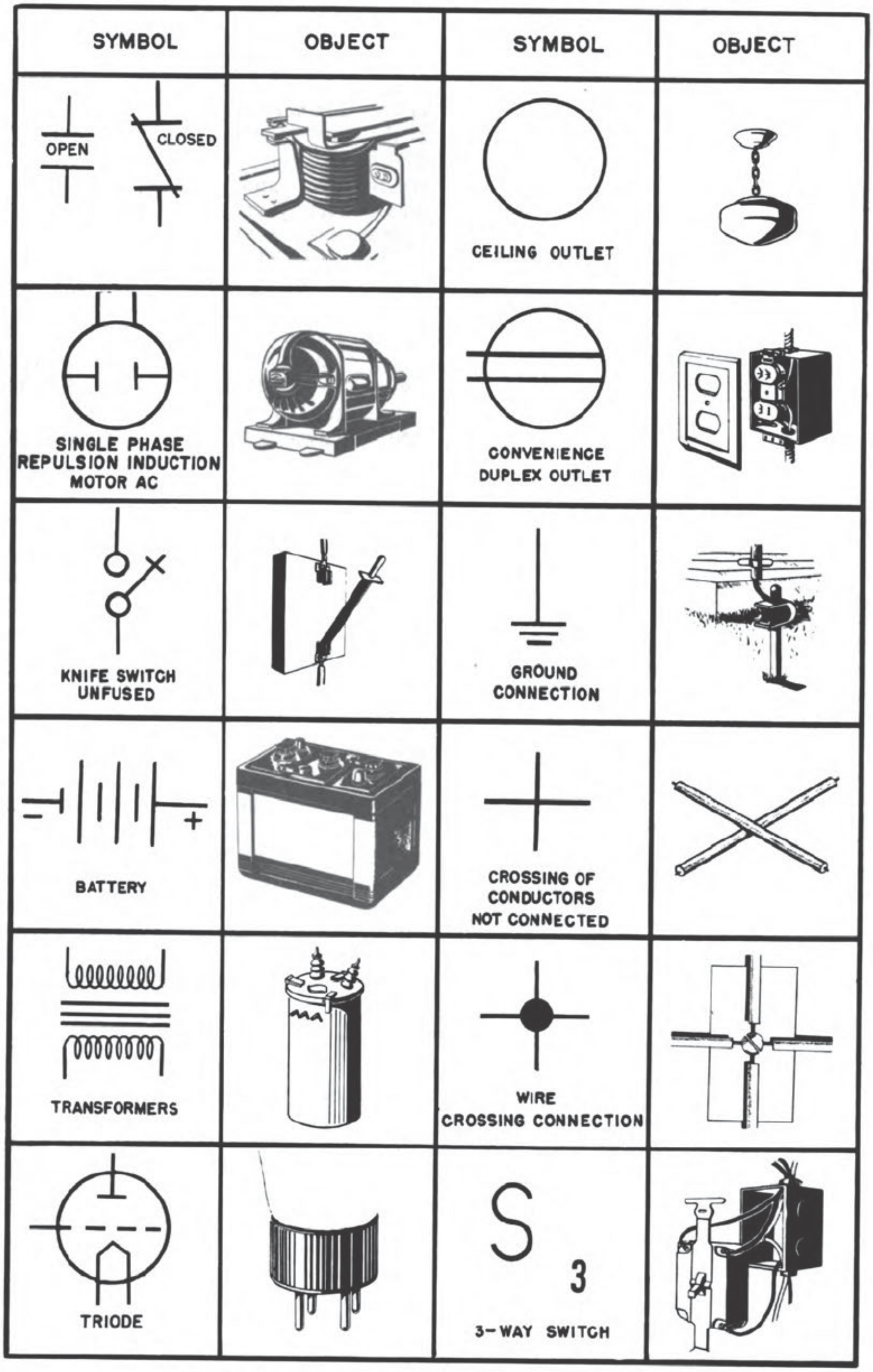


Figure 3-2.—Interpreting electrical symbols. 26.2

The First Class and Chief CE should develop a habit of furnishing sketches with appropriate electrical symbols, to members of his crew that are assigned projects (other than routine jobs). Equipped with a sketch or plan of the work to be done, the men will normally be better informed on what is to be done, will be able to determine the exact amount and type of material required, and will make less errors. This will result in a saving of time and material.

MODIFICATION OF BUILDINGS

BuDocks has prepared a series of drawings (NavDock P-140) to cover most installations used at advance bases. There are occasions, however, when a building is required to be modified or used for another purpose than originally intended.

Let us assume that, with more emphasis being placed on nuclear, biological, and chemical warfare, there is a need to train personnel in disaster control. Figure 3-3 shows a floor plan of a typical advance base storage building, modified by adding an NBC gear storage room, equipment maintenance room, and the layout of the required classroom furniture. Let's further assume that you are to sketch a wiring diagram for the above mentioned floor plan and to provide some general information on the light and power requirements. How would you sketch it?

In general your sketch would probably be similar to the one illustrated in figure 3-3. This particular sketch will serve three important purposes:

1. It will graphically show the originator (P & E officer) the exact location of the lights and power outlets, and give him an opportunity to make changes if necessary, before final approval.
2. It will serve as a blueprint for CEs to follow in the actual wiring of the building.
3. It can be utilized to estimate the amount and type of material required to complete the project.

A simple sketch can be a tremendous help, particularly to third class CEs who have had little or no experience in some phases of wiring.

Let's take a hypothetical case of a power failure caused by a damaged transformer connected delta-delta, three-phase, in a three-transformer bank. The center transformer of the bank is defective. The transformer cannot be readily repaired, and a replacement will not be available for a couple of days. Your immediate decision is to connect the two remaining transformers in an open delta connection and in this way supply approximately 60 percent of the load. You have a third class CE available who has had very little experience in transformer connection, and you feel that he does not understand just how to make an open delta connection. If you draw a rough sketch such as the one illustrated in figure 3-4, showing the third class how to connect the two remaining transformers, open delta, it will be almost impossible for him to err.

A sketch such as the one illustrated in figure 3-4 will help to instill confidence in some of the less experienced personnel in your crew, and give them a better understanding, in this case, of a three-phase, two transformer, open-delta connection.

ADDITION TO EXISTING FACILITIES

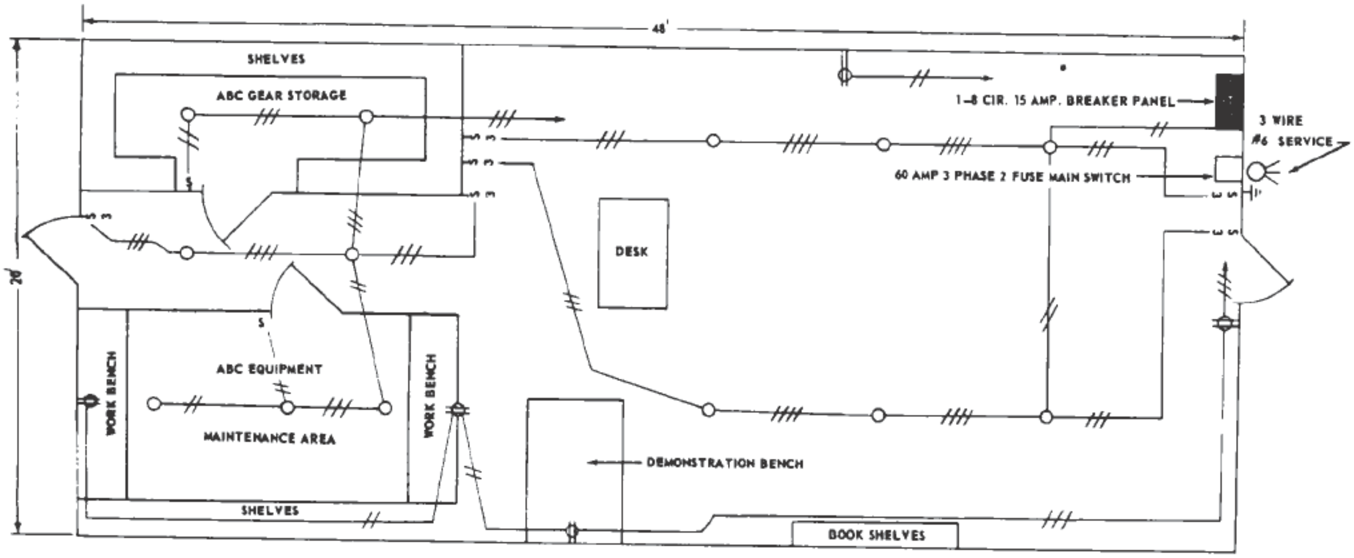
A knowledge of sketching will come in handy when you are required to assign your crew to a job rearranging existing lighting, or to supply additional lighting to increase the foot candle-power. It will also help when you need to add special wiring for additional apparatus or equipment; add switches and outlets due to adding partitions, entrances and exits; and increase power load due to additional electrical consumption over and beyond estimated need.

Switches and Outlets

Normally switches are located near entrances and exists. Your main concern will be whether they are to be a one-way (S), three-way (S_3), or four-way (S_4) switch. Convenient outlets, however, require a little more foresight and planning to properly place them. Observe some of the buildings now being used as offices, note the extension cords required for the desk lights, electrical typewriters, and other electrical equipment. Good planning would eliminate 90 to 100 percent of the extension cords. If you are required to install electrical outlets in a building, give careful consideration to locating a few extra outlets for future expansion or rearrangement of the furniture.

Electrical Apparatus and Equipment

With technological advancements, larger and better equipment frequently requiring more



26.3

Figure 3-3.—An electrical sketch.

power are constantly replacing older and outdated electrical equipment. Sometimes this requires more than adding an extension or another convenience outlet. It may however, involve an increase in voltage and amperage.

Increasing the Power Load

Modifying or making additions to existing facilities may increase the load to a greater value than the safe carrying capacity of present wiring or apparatus. Usually this will be indicated by frequent blowing of fuses and abnormally hot wiring or equipment. When an overload appears to exist, the actual current should be measured with an ammeter. Wattage of all lamps, devices, and other equipment connected to the overloaded circuit should also be checked. An apparently overloaded circuit may sometimes be only a partially grounded circuit. If an overload is discovered, part of the load should be transferred to another circuit or the wiring should be replaced to provide adequate current capacity.

There may be instances when several buildings in a specific area require such an increase in load demand that the distribution transformer serving that area becomes inadequate; thereby requiring it to be replaced with a larger one.

WATERFRONT FACILITIES

The design of power systems for waterfront facilities is based on standard criteria and practices similar to those for other locations. Modifications may be necessary, however, to enable them to withstand moist usually salt-laden air, or to make them suitable in locations that are alternately wet and dry. Corrosion prevention and safe wiring practices are also important considerations.

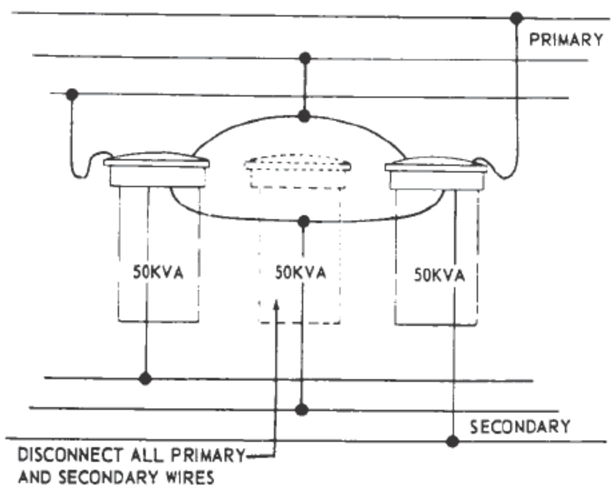
Duct Lines

When you are required to use conduit for protecting wire around waterfront facilities, you should use fiber or asbestos cement duct. Rigid-steel conduit should be used ONLY to meet particular design problems. When necessary to install conduits where they will be exposed to wave action, as underneath piers or similar structures, asbestos-cement conduit, supported with steel hangers at not more than 5-foot intervals, is recommended.

Pier Outlets

Pier outlets for ship-service or portable equipment should be the protected type and should supply 440 volt, 3-phase power. The outlet is basically a 3-pole, 3-wire receptacle, with circuit-breaker protection, housed in a watertight enclosure of heavy welded-steel plate.

The nominal rating of the outlet is 200 or 400 amperes. For capacities between 400



26.4

Figure 3-4.—A sketch of two transformers connected open delta.

and 1600 amperes, 400-ampere outlets should be provided in a number sufficient to total the required number of amperes. When a single outlet is designed for capacities of more than 1600 amperes, it should have bus bars and provisions for bolting on cable connections, and should be housed in a suitable enclosure.

The design of the installation should assure coordination between the interrupting ratings of the circuit breakers in the feeders and the circuit breakers at the outlets. A single outlet for more than 1600 amperes should have a circuit breaker at the outlet, if practicable, or in the feeder at the point of distribution.

Lighting Units

When lighting for a pier or dockside is planned, there are many factors to be considered. Among these are the best locations for the lights, amount of light needed, types of luminaires needed to meet the use of the pier or dock, and the amount of traffic in the area. Your selection of luminaires will affected the location and how they will be mounted. At all times keep in mind the service the pier is to give, the types and sizes of ships to be served, and the equipment that will be working on the pier.

TECHINICAL REQUIREMENTS

You must have a basic technical knowledge of design before you can sketch and design wiring plans to meet specified Navy requirements.

Most of the technical guidance for design and planning of waterfront facilities, building or interior wiring, street or exterior lighting, and other types of electrical guidance is the responsibility of BuDocks. Some of these design criteria will be discussed in this chapter.

WATERFRONT FACILITIES

At waterfront facilities, a ground system that shall measure not more than 10 ohms should be provided for all permanent electrical equipment. The ground system should be in accordance with the acceptable Navy electrical code. The water-piping system on a structure is recommended as a ground for electrical equipment enclosures on the structure. Stranded-copper-wire ground conductors should be used to interconnect all electrical equipment enclosures and the water-pipe ground. The sizes of the ground conductors from enclosures, cable sheaths, steel conduits, transformer cases, or other devices are determined by the American Wire Gauge (AWG) size of conductors enclosed, as shown in table 3-1.

Table 3-1.—American Wire Gauge Conductor Sizes

Size (AWG) of largest conductor or equivalent for multiple conductors	Ground Conductor AWG No.
2 or smaller	8
1 or 0	6
00 or 000	4
Over 000 to 350,000 CM*	2
Over 350,000 CM to 600,000 CM	0
Over 600,000 CM to 1,100,00 CM	00
Over 1,100,000 CM	000

* Circular mils.

The ground conductor on the structure should be protected at places it could be damaged. It is preferable to install the ground conductor in conduit or in the duct system in order to provide mechanical protection, but the ground conductor may be installed in the open if the installation is such that the conductor is

thoroughly protected. When lead-covered cables are installed in ducts which may be partially immersed in water, or when water resulting from condensation or other causes remains in the ducts for long periods, the ground conductor in the duct line should be insulated with not less than 1/32 of an inch of a polyvinyl chloride type of insulation. This insulation reduces the possibility of corrosion of the lead sheath.

Structures that are not adjacent to a water-piping system should have a ground conductor system extended from the grounded devices to a driven ground rod system. The ground conductor in this case should be No.6 AWG minimum and need be no larger except under conditions where a larger size will provide additional mechanical strength. Where it is not practical to properly maintain an onshore ground rod system adjacent to the pier, metal plates lowered to the bottom of the water should be used. The conductor connecting these plates to the No.6 AWG conductor on the structure should be at least No. 2 AWG stranded copper wire in order to provide sufficient mechanical strength.

Cable and wire used in waterfront facilities should be a type suitable for installation in wet locations. When specified type RHL, heat-resistance rubber with lead covered cable, should be used for cables in sizes up to and including No.2 AWG, and type VCL, varnish cambric lead covered cable, for sizes larger than No. 2 AWG. Wiped joints should be employed in making splices. At terminations an approved type of compound-filled terminal device should be used. The National Electric Code states that for damp or wet locations wire and cables No. 8 and smaller shall be type RHWN (neoprene jacket) or THWN (nylon jacket). Wire sizes No. 6 and larger will be RHWN (neoprene jacket). When specified use RHL.

EXTERIOR LIGHTING

When exterior lighting is required for streets, roadways and piers at naval activities, careful consideration should be given to the type and design of the system and to the mounting luminaires, so as to obtain a uniform level of illumination of sufficient intensity without glare.

The tendency, in the case of street lighting at naval activities, is toward higher levels of illumination and the use the pendant type of luminaire in place of the post type with general diffusing fixtures.

Modern practice is to install the luminaires over the street for better distribution of light. If you are assigned the project of planning and lighting at any naval activity, you should exercise care in specifying the mounting of luminaires so that interference with moving cranes and large pieces of equipment will be avoided. This is particularly applicable to areas near waterfronts, railroad tracks, and piers used for general repair and fitting-out and supply.

Street Lighting Intensities

Lighting intensities should conform to those given in table 3-2 for pedestrian and vehicular traffic. In general, waterfront streets, main streets with railroad tracks in the industrial sections of large yards and general repair facilities, and fitting-out and supply piers should be classified for medium pedestrian and medium vehicular traffic. For cross streets in the industrial sections of large yards, residential streets, main streets in secondary naval activities, hospitals, and the like, the classifications should be light pedestrian and light vehicular traffic. Foot-candle intensity calculations are generally made by the average flux method or the point-by-point method. In employing the horizontal and vertical candle-power distribution, curves are used. These curves together with applicable data are available from manufactures of street lighting equipment.

Table 3-2.—Street-Lighting Intensities

Horizontal foot-candles				
Pedestrian traffic	Vehicular traffic classification with number of vehicles per hour in both directions			
	Very light (under 150)	Light (150-500)	Medium (500-1200)	Heavy to heaviest (1200 up)
Heavy	0.6	0.8	1.0	1.2
Medium	0.4	0.6	0.8	1.0
Light	0.2	0.4	0.6	0.8

Luminaires

A luminaire is the complete assembly of the light unit, including the series bayonet receptacle the series socket with film disk, the reflector or refractor, the lamp, and enclosing glassware if any.

The choice of the luminaire is governed by the mounting height, spacing, and transverse location of the fixture. Good practice requires that most of the light from a luminaire be directed toward the street, and be distributed to assure good utilization. Some light, however, should be directed back to the curb line to provide illumination on the sidewalk and adjacent areas or along the edges of piers. Incandescent and high-intensity mercury-vapor lamps are the most commonly used light sources. Sodium vapor is seldom employed because of its amber color, except for identifying a caution point at a street or road intersection.

Mounting Heights

In determining mounting heights for luminaires, the light should be kept as high as practicable to give greater and more uniform distribution of light. Overhead street lights, or lights located at street intersections, should be mounted between 22 to 25 feet high. For ornamental installations, where spacing is usually closer, this height may be reduced to 18 feet if overhanging luminaires do not conflict with street clearance requirements.

Control

Most street-lighting systems are automatically controlled by a time clock or photocell device. Systems with a single primary feed common to all transformers should be controlled by an automatic switch in the primary with the control switch in an attended station. When two or more transformers with separate primary feeds occur in the system, the control may be by relays operating on the cascade system or by carrier current.

INTERIOR WIRING

The first step in planning the circuit for any wiring installation is to determine the connected load per outlet. The load per outlet can be obtained in several different ways:

1. The most accurate method of determining load per outlet is made by obtaining the stated value from the blueprints or specifications. If the specifications are not available, the blueprints in many cases designate the type of equipment to be connected to specific outlets. Though the equipment ultimately used in the outlet may come from a different manufacturer, equipment standards provide the electrician with assurance that the outlets will use approximately the same wattage. If the equipment is available, the nameplate will list the wattage used or amperes drained. If not, data similar to that given in tables 3-3 and 3-4 should be obtained. Table 3-3 gives the average wattage consumption of electrical appliances, and table 3-4 lists the current requirements for small motors of various horsepower ratings.

2. To provide adequate wiring for systems where the blueprints or specifications do not list any special or appliance loads, the following general rules will apply:

a. For heavy duty outlets or mogul size lampholders, the load per outlet should be figured at 5 amperes each.

b. For all other outlets, both ceiling and wall, the wattage drain (load per outlet) should be computed at 1.5 amperes per outlet.

3. The total outlet load for general illumination may also be determined on a watts-per-square-foot basis. In this load-determination method, the floor area of the building to be wired is computed from the outside dimensions of the building. This square footage area is then multiplied by the standard watts-per-square-foot requirement based on the type of building to be wired. Table 3-5 lists these constants along with a feeder-demand factor for various types of building occupancies.

Maximum Load Demand Per Building

In some building installations the total possible power load may be utilized at the same time during daily operation. In this case, the generating capacity of the power supply, which must be kept available for these buildings, is equal to the connected load. In the majority of building installations where personnel will work, the maximum load which the system is required to service is much less than the possible total connected load. This power load which is set at some arbitrary figure below the possible total connected load is called the "maximum demand" of the building.

Demand Factor

The ratio of "maximum demand" to possible total connected load in a building expressed as a percentage is termed "demand factor." The determination of maximum building loads (maximum demand) can be obtained by the use of standard demand factors as shown in table 3-5. For example, if the possible total connected load in a warehouse is 22,500 watts, using the demand factors listed in table

3-5 for warehouses, the maximum building load can be obtained as follows:

Table 3-3.—Wattage Consumption of Electrical Appliances

Appliance	Average wattage
Blanket	150
Clock	3
Coffeemaker	550
Chafing dish	600
Dishwasher	100
Egg boiler	250
Fan, 8-inch	30
Fan, 10-inch	35
Fan, 12-inch	50
Frying pan	600
Griddle	450
Grill	600
Heater (radiant)	1000
Heating pad	50
Hotplate	660
Humidifier	500
Immersion heater	300
Iron	1000
Ironer	1320
Mixer	200
Phonograph	40
Range	8000
Refrigerator	250
Radio	100
Roaster	1320
Sewing machine	75
Soldering iron	200
Sunlamp	450
Television	300
Toaster	450
Vacuum cleaner	160
Washing machine	175
Water heater	2000
Waffle iron	660

Table 3-4.—Motor Currents

Horsepower	Full-load amperes			
	120 v. 1 phase	240 v. 1 phase	208 v. 3 phase	416 v. 3 phase
1/6	3.1	1.6	...	...
1/4	4.4	2.2	...	...
1/2	7.1	3.6	2.1	1.1

Table 3-4.—Motor Currents—Continued

Horsepower	Full-load amperes			
	120 v. 1 phase	240 v. 1 phase	208 v. 3 phase	416 v. 3 phase
3/4	9.8	4.9	3.0	1.5
1	12.5	6.3	3.7	1.9
1-1/2	17.7	8.9	5.3	2.7
2	23.1	11.6	7.0	3.5
3	32.6	16.3	9.6	4.8
5	54.0	27.0	16.0	8.0

100 percent of the first 12,500 watts equal 12,500, 50 percent of the remaining 10,000 watts equals 5000; therefore, the total maximum building load can be safely assumed to be 12,500 plus 5000 watts or 17,500 watts. This does not mean that the building load cannot exceed 17,500 watts; it can go as high as 22,500 watts. It only means that for this type building (warehouse) the maximum load which the wiring system is required to service is 17,500 watts.

Type of Distribution

The electrical power load in any building cannot be properly circuited until the type and voltage of the central power-distribution system is known. The voltage and the number of wires from the powerlines to the buildings are normally shown or specified on the blueprints. However, the Construction Electrician should check the voltage and type of distribution at the power-service entrance to every building in which wiring is to be done. This is especially necessary when the CE is altering or adding circuits. The voltage checks are usually made with an indicating voltmeter at the service-entrance switches or at the distribution load centers. The type of distribution is determined by visual check of the number of wires entering the building.

If only two wires enter the building, the service is either direct current or single-phase alternating current. The voltage is determined by an indicating voltmeter. At advance bases, two wires entering a building usually indicate single-phase a-c. When three wires enter a building the service is usually single-phase, or three-phase a-c.

Grounding

A ground system is provided by installing a No. 8 wire protected in armor or conduit

Table 3-5.—Standard Loads for Branch Circuits and Feeders and Demand Factor for Feeders

Occupancy	Standard load, watts per square foot	Feeder demand factor, percent
Armories and auditoriums	1	100%
Banks.	2	100%
Barber shops.	3	100%
Churches	1	100%
Clubs.	2	100%
Dwellings	3	100% for first 3,000 watts, 35% for next 117,000, 25% for excess above 120,000.
Garages	0.5	100%
Hospitals	2	40% for first 50,000 watts 20% for excess over 50,000.
Office buildings	2	100% for first 20,000 watts, 70% for excess over 20,000.
Restaurants	2	100%
Schools	2	100% for first 15,000 watts, 50% for excess over 15,000.
Stores	3	100%
Warehouses	0.25	100% for first 12,500 watts, 50% for excess over 12,500.
Assembly halls	1	100%

or a No. 6-gage bare wire connecting the neutral wire either to a water pipe or a driven pipe or rod used as a ground electrode. The wire is attached to the water pipe or conduit by a special clamp or bushing ground-connector clamp after the pipe or conduit has been filed or sandpapered clean to make a good electrical contact.

The National Electrical Code requires that on systems supplying interior wiring circuits, one wire of the circuit shall be grounded, provided that the voltage from any other conductor to ground will not exceed 150 volts on alternating currents systems.

Circuits operating at less than 50 volts need not be grounded, provided the transformer supplying the circuit is connected to a grounded system.

Wire Sizes

Wire sizes No. 14 and larger are classified in accordance with their maximum allowable current-carrying capacity based on their physical behavior when subjected to stress and temperatures of operating conditions. A 14-gage wire is the smallest wire size permitted for use in interior wiring systems except that low voltage (50 volts or less) systems use No. 18 from the outlet to the switch box.

The determination of wire size to be used in circuits is dependent on the voltage drop coincident with each size. The size of the conductor used as a feeder to each circuit is also based on voltage drop, and should be selected so that the voltage drop from the

branch circuit supply to the outlets will not be more than 3 percent for power loads and 1 percent for lighting loads. Table 3-6, which is based on an allowable 3 percent voltage drop, lists the wire sizes required for various distances between supply and load, at the different amperages.

Table 3-6 also lists the service-wire requirements and capacities. The minimum gage for service-wire installation is No. 8 wire, except for installations consisting of a single branch circuit in which case they shall not be smaller than No. 12. Though this may seem to contradict the minimum wire size listed, the service-wire sizes are increased because they must not only meet the voltage-drop requirement but also be inherently strong enough to support their own weight, plus any additional loading caused by climatic and other conditions, such as ice, branches, and so on.

WIRING FOR HAZARDOUS LOCATIONS

Hazardous locations requiring special wiring considerations are divided into three classes by the National Electric Code.

Class I.—For locations in which highly flammable gases and liquids such as hydrogen, gasoline, alcohol, and so on, are manufactured, used or handled, all wiring must be in rigid metal conduit with explosion-proof fittings. All equipment such as circuit breakers, fuses, motors, generators, controllers, and so on, must be totally enclosed in explosion-proof housings.

Class II.—In locations where combustible DUST is likely to accumulate in the air in sufficient quantities to produce explosive mixtures, all equipment must be in dustproof cabinets with motors and generators totally enclosed or in totally enclosed fan-cooled housings.

Class III.—Locations in which easily ignitible FIBERS or MATERIALS producing combustible flyings (particles suspended in the atmosphere) are handled or used, such as a woodworking shop or plant, require wiring of the same type as in Class II. If the atmosphere is such that combustible flyings will collect on motors or generators they must be enclosed as in Class II.

INSTALLATION IN HAZARDOUS LOCATIONS

The Code further specifies standards for particular types of installations. For example, some of these special requirements for hospital operating room installation are as follows:

All equipment installed in the operating room must be explosion proof and provided with a suitable equipment ground.

In locations used for anaesthetics, an underground electrical distribution system is required to reduce the hazards of electric shocks and arcs in the event of insulation failure. Alternating-current circuits shall be insulated from the conventionally grounded alternating supply by means of one or more transformers which isolate the circuits electrically from the main feeder line. Direct-current circuits shall be insulated from their grounded feeders by means of a motor generator set or suitable battery system.

All services equipment including switch and panel boards must be installed in nonhazardous locations.

Ceiling suspended lighting fixtures shall be suitably protected against mechanical injury.

Explosion-proof switches, receptacles, motors or similar conduit installations must be isolated from the rest of the conduit runs by sealed fittings. This type fitting has a removable plug which permits the insertion of a sealing compound, sealing off the points of possible explosion from the remaining conduit areas.

Nonmetallic tools such as rubber-head hammers and spark free drills must always be used when making electrical repairs or installations in the area.

PLANNING WORK FROM BLUEPRINTS

Whenever you are assigned a major project, you will normally be given a set of blueprints which will contain the plot or site plan, floor plans, electrical plans, and so on.

Your main concern will be the plot or site plan and all the prints dealing with the electrical phase of the project. You should also, however, study the complete set of plans so that you can coordinate your job with the jobs of the chiefs of the other ratings.

STUDYING THE LOCATION (PLOT)

The primary purpose of the plot or site plan is to show the location of the proposed project, the existing buildings, roads, walkways and other features in the vicinity, and the new or proposed buildings. (See fig. 3-5.)

Wire size for 120-volt single phase circuit

Load (amps.)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG) — Distance one way from supply to load (ft.)												
			50	75	100	125	150	175	200	250	300	350	400	450	500
15	14	. 10	14	12	10	8	8	6	6	6	4	4	4	2	2
20	14	10	12	10	8	8	6	6	6	4	4	2	2	2	2
25	12	8	10	8	8	6	6	4	4	4	2	2	2	1	1
30	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
35	12	6	8	6	6	4	4	4	2	2	1	1	0	0	2/0
40	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
45	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
50	10	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
55	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
60	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
65	8	4	6	4	4	2	2	1	0	2/0	2/0	3/0	4/0	4/0	
70	8	4	6	4	2	2	1	1	0	2/0	2/0	3/0	4/0	4/0	
75	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
80	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
85	6	4	4	4	2	1	1	0	2/0	3/0	3/0	4/0			
90	6	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0			
95	6	2	4	2	2	1	0	2/0	2/0	3/0	4/0				
100	4	2	4	2	2	1	0	2/0	2/0	3/0	4/0				

Wire size for 220-volt three-phase circuits

Load (amps.)	Minimum wire size (AWG)	Service wire size (AWG)	Wire size (AWG) — Distance one way from supply to load (ft.)												
			100	150	200	250	300	350	400	500	600	700	800	900	1,000
15	14	12	14	12	10	8	8	8	6	6	6	4	4	4	2
20	14	10	12	10	8	8	6	6	6	4	4	4	2	2	2
25	12	8	10	8	8	6	6	6	4	4	2	2	2	2	1
30	12	8	10	8	6	6	6	4	4	2	2	2	1	1	0
35	12	8	10	8	6	6	4	4	4	2	2	1	1	0	0
40	10	6	8	6	6	4	4	4	2	1	1	1	0	0	2/0
45	10	6	8	6	6	4	4	2	2	2	1	0	0	2/0	2/0
50	10	6	8	6	4	4	2	2	2	1	0	0	2/0	2/0	3/0
55	8	6	8	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0
60	8	6	6	6	4	2	2	2	1	0	0	2/0	3/0	3/0	4/0
65	8	4	6	4	4	2	2	2	1	0	2/0	2/0	3/0	3/0	4/0
70	8	4	6	4	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0
75	6	4	6	4	2	2	2	1	0	2/0	2/0	3/0	4/0	4/0	
80	6	4	6	4	2	2	1	1	0	2/0	3/0	3/0	4/0	4/0	
85	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
90	6	4	6	4	2	2	1	0	0	2/0	3/0	4/0	4/0		
95	6	4	6	4	2	1	1	0	2/0	3/0	3/0	4/0			
100	4	2	4	2	2	1	0	0	2/0	3/0	4/0	4/0			
125	4	2	4	2	1	0	2/0	2/0	3/0	4/0					
150	2	2	2	2	0	2/0	2/0	3/0	4/0						
175	2	1	2	1	0	2/0	3/0	4/0	4/0						
200	1	0	1	0	2/0	3/0	4/0	4/0							
225	0	0	0	0	2/0	3/0	4/0								
250	2/0	2/0	2/0	2/0	3/0	4/0									
275	3/0	3/0	3/0	3/0	3/0	4/0									
300	3/0	3/0	3/0	3/0	4/0										
325	4/0	4/0	4/0	4/0											

Table is based upon approximately 3% voltage drop.

Table 3-6.—Voltage drop tables

In the plot plan shown in figure 3-5 you will note that at several locations the removal of existing conductors is required; also note the relocation of generator station 1 and 2A. You will find on the plot plan references to other prints for more detailed information on particular portions of the system. The plot may indicate how high overhead lines are to be strung and how deep cables are to be placed in the ground. If these requirements are not shown on the plot plan you should always be able to find them in the specifications.

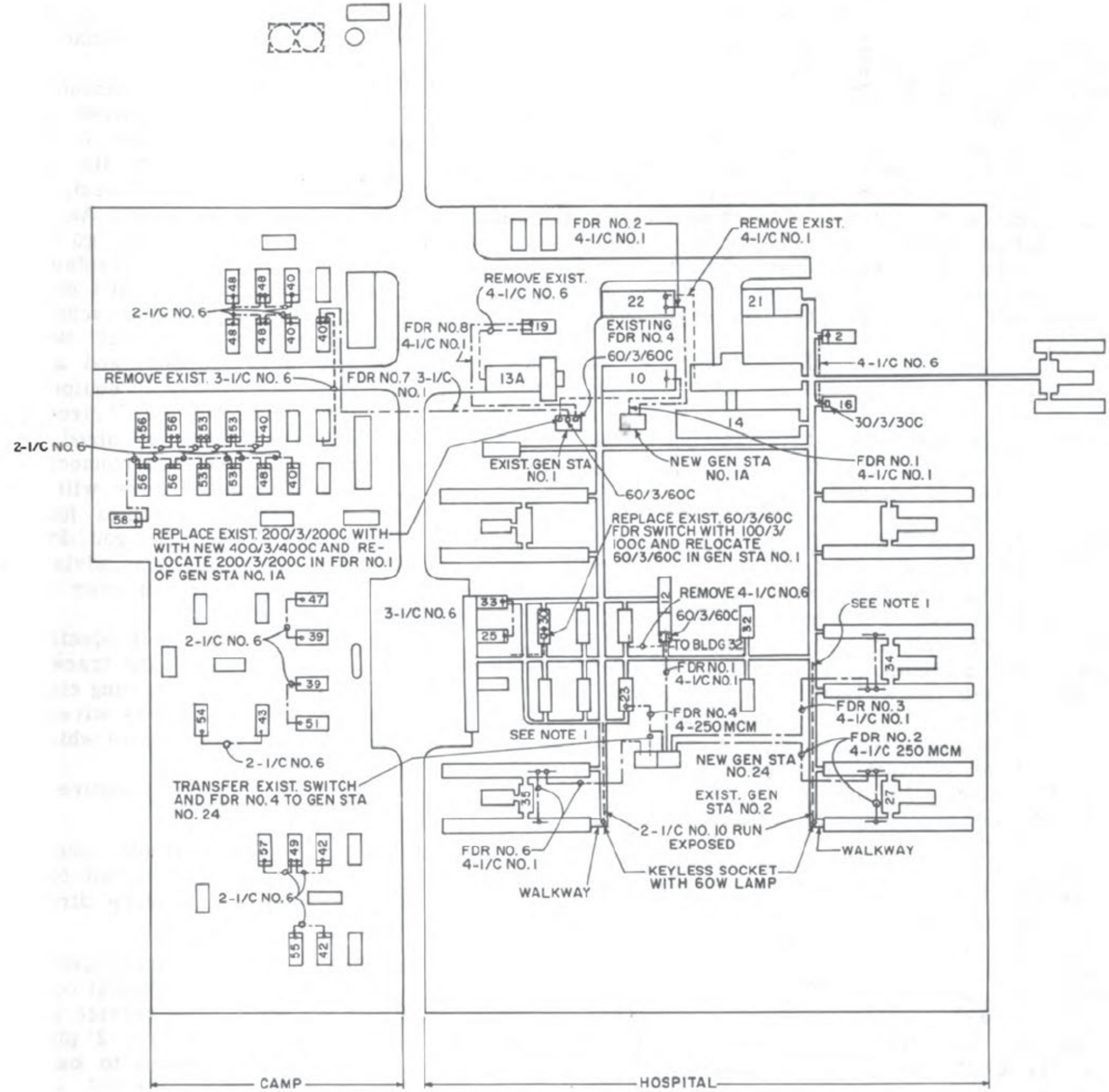


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Figure 3-5.—Plot plan showing location of work to be done.

LAYING OUT THE JOB

Laying out the job covers several steps that you must perform in order to accomplish a job (project) in the most efficient manner and within the least amount of time.

Some of the items that have to be considered as you lay out a job include material estimating, personnel organization (such as crews needed and size of each crew), determining tools needed for each crew, and deciding what construction equipment you will need and when.

The equipment chief can schedule the latter for you or let you know if it's already scheduled for when you want it; if it is, you can adjust your schedule to better fit the whole project. Don't forget to keep in mind the experience of your crews. The Critical Path Method (CPM) is a very good tool to use in planning your day to day jobs. The CPM is covered later in this chapter.

ESTIMATING

Estimating includes the determination of the amount and kind of work to be performed, the breaking down of this work into work elements, and the determining of the quantities of materials, labor, and equipment needed to perform this work. Estimating is an important part of planning Seabee jobs. Work element estimates provide the basis for preparing the detailed estimates of material, equipment, and manpower requirements. For example, the work element might show 1000 square feet of 12" concrete block wall to be constructed. The material estimate will express this wall in terms of the quantities of sand, mortar, lime, and 12" block. The manpower estimate will show the manday requirements and the equipment needed.

A very good book to use as a reference in estimating is the Seabee Planner's and Estimator's Handbook, NavDocks P-405. This handbook contains information which can be used in planning and estimating the projects normally undertaken by Seabees. The information covered in this chapter is to give you a working knowledge of estimating, planning and the CPM. You are not expected to be a full time planner and estimator from studying this chapter, but, you will be able to use the CPM, planning and estimating, as useful tools in your every day work.

MATERIAL TAKE OFF

To estimate the amount of wire and electrical equipment you will need in any particular room or building, you will need an electrical sketch or plan similar to the one shown in figure 3-6. Determining the amount of wire and electrical equipment required for a project is a time consuming and important part of your job, particularly when the bill of material is not given.

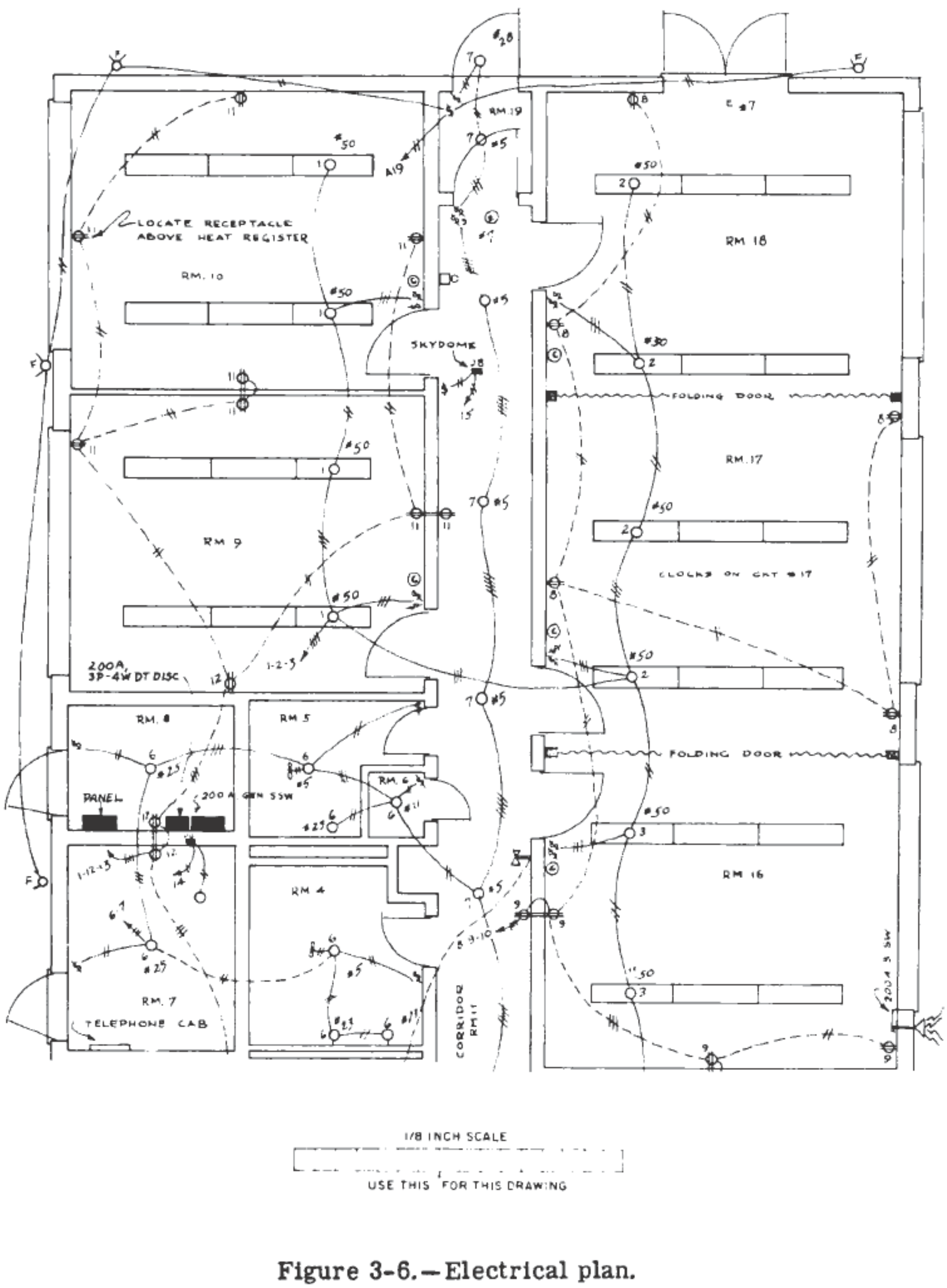
The best way to estimate the amount of wire and electrical equipment required is to start with the first circuit and trace it from the service panel or fuse box to the first outlet or switch, then on to the next, and follow that circuit through to the end. As soon as you complete tracing one circuit, go back and count the number of required receptacles, switches, outlets, junction boxes, and so on, and list them systematically on a separate sheet of paper. Then pick up circuit No. 2 and trace it through to the end, and again go back and count the electrical equipment required. You will continue this for all circuits. In estimating the amount of wire required, you must add 1 foot of wire at each connection; this means that every run of wire will require 2 extra feet of wire, 1 extra foot at each end. Also, to be sure that you do not miss any circuit or branches, it is advisable to use a colored pencil to trace over each branch circuit as you cover it.

To get some actual practice in electrical estimating, refer to figure 3-6 and trace the No. 1 lighting circuit. The No. 1 lighting circuit located in rooms 9 and 10, and the wires for this circuit are placed in the conduit which is located along the ceiling.

The electrical plan shown in figure 3-6 is scaled to 1/8 inch equals a foot.

Beginning with the No. 1 circuit, (actually circuits No. 1, 2 and part of circuit No. 3) use a scale or rule and measure directly from each point listed below:

1. From homerun symbol (arrow pointing back to the service entrance switch) at ceiling outlet northwest of room 9 to service panel (room 8) is 1 7/8" or 15' plus 2' plus 3' (The 3' is the amount required to be run from the ceiling to the service panel, which is normally located at eye level or 5 feet from the floor, which would be 3 feet from the ceiling.)



26.6

Figure 3-6.—Electrical plan.

NOTE: The plan indicates that there are five wires in this conduit.

The amount of wire required is:

2 white wires
(neutrals) . . . . . . 30' + 4' + 6' = 40'
1 black wire . . . . . 15' + 2' + 3' = 20'
1 red wire . . . . . . 15' + 2' + 3' = 20'
1 blue wire . . . . . . 15' + 2' + 3' = 20'

2. From northwest ceiling outlet room 9, to switch in same room is 1/2" or 4'.

NOTE: The plan indicates there are three wires.

The amount of wire required is:

3 black wires . . . 12' + 6' + 12' (ceiling to switch) 4' = 30'

3. From northwest ceiling outlet in room 9 to southwest ceiling outlet in same room is 7/8" or 7'.

NOTE: The plan indicates there are three wires. The amount of wire required is:

1 white (neutral) . . . . . 7' + 2' = 9'
2 black wires . . . . 14' + 4' = 18'

4. From southwest ceiling outlet of room 9 to northwest ceiling outlet of room 10 is 15/16" or 7 1/2'.

NOTE: The plan indicates there are two wires.

1 white wire
(neutral) . . . . 7 1/2' + 2' = 9 1/2'
1 black wire . . . . 7 1/2' + 2' = 9 1/2'

5. From the northwest ceiling outlets, room 10 to switch in same room is 9/16" or 4 1/2'.

NOTE: The plan indicates there are three wires. The amount required is:

3 black wires . . . 13 1/2' + 6' + 12' (4' ceiling to switch) = 31 1/2'

6. From northwest ceiling outlet in room 10 to southwest ceiling outlet in same room is 7/8" or 7 feet.

NOTE: The plan indicates there are two wires. The amount of wire required is:

1 white wire . . . . 7' + 2' = 9'
1 black wire . . . . 7' + 2' = 9'

To total up the number of feet of the various color wire required, you may proceed thusly:

Measurement number	white wire	black wire	red wire	blue wire	conduit
1	40'	20'	20'	20'	18'
2	0	30'	0	0	8'
3	9'	18'	0	0	7'
4	9 1/2'	9 1/2'	0	0	7 1/2'
5	0	31 1/2'	0	0	8 1/2'
6	9'	9'	0	0	7
TOTAL	67 1/2'	118'	20'	20'	56'

When possible compute your measurements rather than scale. In order to make allowances for going around some unaccounted obstruction, and also for inaccuracies in measurement due to shrinkage in blueprint paper when making reproduction, you must add 10 percent. For example, you would actually need 129.8' of black wire; 118' X 10%, would give you 11.8'. Add this to 118 and you would get a total of 129.8'/.

Besides the wire and conduit you must determine the amount of wire nuts, switch boxes, switches, outlet boxes, conduit straps for holding conduits (usually 1 for every 5 feet of conduit), bushings and locknuts for conduits, and finally lighting fixtures and wall plates for the switches.

Because the amount of work performed by an individual depends on many factors including climate,, type of work, equipment available, ability, experience, interest, and many others, productivity rates vary from time to time and place to place. The norms shown in table 3-7 are averages and have been adapted to the field type construction associated with advanced base construction.

Adequate supervision by the crew chief, and the importance of the ingenuity and resourcefulness of the crew members, should not be underestimated. This table is only to serve as a guide; after you get to know your crew you can probably determine the installation time more accurately.

Table 3-7.—Construction Norms for Electrical Work

Complete installation for outlet (Roughing for box, conduit, wiring and connections)	Complete Unit Per Man-Day Minimum Acceptable	Average	Outstanding Performance
With Armored Dable or 1/2" flexible conduit.	4	8	12
With Rigid Conduit, all sizes	3	5	7
Installing Outlet Boxes	Units Per Man-Day		
Ceiling and wall outlet boxes	20	25	30
Service switches & base plugs	25	35	55
Meter, fuse box, switch box, etc.	4	6	8
Installing Rigid Conduit & Connect	Linear Feet Per Man-Day		
1/2" and 3/4"	50	70	80
1" and 1 1/4"	45	55	65
1 1/2" and 2"	30	40	50
Installing 1/2" Flexible Conduit	100	150	200
Pulling and Installing Wire in Conduit			
#8 to #14 gage	400	500	600
#1 to #6 gage	150	250	350
Installing Armored Cable	100	150	200
Installing and Wiring Fixture	Units Per Man-Day		
Ceiling or Wall Light	9	14	20
Switch, Base or Fuse Plug	20	25	30

Crew Pattern:- Two Electricians for each crew.

Productivity: For a building with 1000 linear feet of 1/2" and 3/4" rigid conduit; 76 outlets; 21 light fixtures; 25 switches; a meter, fuse, and switch box; it will take 24 man-days to completely install the electrical work, computed as follows:

Installation of:

76 outlets at 4 per man-day	19.0 man-day
Meter, fuse and switchbox at 6 per man-day	.5
21 light fixtures at 14 per man-day	1.5
25 switches at 25 per man-day	1.0
Miscellaneous and Test	2.0
	24.0 Man-days

Note: The prefabrication of the rigid conduit will increase productivity.

TESTING AND INSPECTING

After the construction work is finished you still have two more responsibilities. One is testing the entire circuit; the other is getting the job inspected. Testing the circuits consists of checking for grounds, shorts, and opens, and also testing the resistance value of the insulation, splices, insulators, and so forth.

Inspection consists in getting your work approved by the project officer. He will check the splices, connections, workmanship, and very likely will insist that the insulation tests be conducted in his presence. He will require

that you accompany him on his tour of inspection. So be prepared to answer any questions he may ask.

CRITICAL PATH METHOD (CPM)

In recent years a new system of project planning, scheduling and control has come into existence and into use in the construction battalions and PW departments throughout the Navy. CPM techniques may be carried out with computers, but for our use we will use hand computation. In most of the projects the Seabees are involved in, hand computation is the method used. The overall objective is to enable the battalion to plan and control small and medium-sized projects using CPM. Larger projects may be handled by breaking them down into subprojects.

CPM came into being because it was believed that traditional methods were inadequate for controlling large-scale engineering projects. It was thought that a high degree of coordination could be obtained if all of the information relevant to the planning and scheduling of the project functions could be combined into a single master plan. This plan could coordinate all of the many different efforts required to accomplish a single objective. The technique had to be very simple and as nearly foolproof as possible, if human beings were to cope with the complexity of a project. One of the main advantages of this technique (CPM) is that it not only visually displays the various stages of the project, but it also shows their interdependency.

PLANNING

There are difficulties with traditional methods due to the fact that the estimator attempts to consider hundreds of details at once: work elements; required materials; equipment and manpower; and such factors as the local availability of materials, expected weather conditions, haul distances from local quarries, gravel pits, and so forth. This detailed information often winds up in the form of separate schedules for material, equipment and manpower, which are difficult to coordinate. The first step is to separate the planning of a project from the scheduling. To accomplish this is to first break down the project into work elements and thereby establish the relationships between these work elements. Only when the relationships among the work elements have been established can scheduling begin. Two of the basic ground rules of CPM are that planning and scheduling are considered to be two distinctly separate operations, and that planning always must precede scheduling.

ARROW DIAGRAM

The relationships established among the elements led to the use of arrow diagrams instead of several sets of bar charts. The tail of the arrow represents the start of the job and the head represents the completion of the job or work element. The resulting diagram shows a network of arrows which show not only what jobs follow each other, but which jobs could be performed in parallel with each other. The arrow diagram is the heart of the CPM system. It is the graphical display of the various work elements, each represented by an arrow. These arrows are connected together to show a continuous flow of activity from beginning to end of project. There are certain basic rules which govern the construction of an arrow diagram:

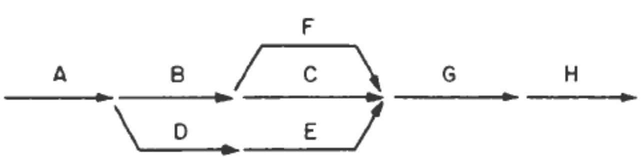
1. A work element is represented by an arrow, the tail signifying the start and the head signifying the completion of that element.
2. Any two events may be directly connected by only one arrow.
3. Arrows imply logical sequence only; neither arrow length nor bearing have any significance.
4. Diagrams should have only one beginning event and one ending event; this is to avoid confusion and to lend continuity.
5. Before a work element may begin, all predecessor work elements must be completed.
6. Every event number must be preceded by a smaller event number.

When job duration times are associated with each arrow, the longest path through the diagram in terms of time equals the project duration. Furthermore, every job on the longest path is critical, in that if anything delays it, the whole project will be delayed. (Hence the term critical path.) The remainder of the jobs are noncritical, because there is more time available in which to complete them than is required. If the project falls behind, only the critical jobs need be expedited in order to catch up. If a noncritical job is not done in time it may become critical, causing the critical path to

change. Many times critical jobs are dependent on noncritical jobs that become critical when not completed on time. In setting up a diagram for a project we have to analyze the project. A project plan is made without considering time or the availability of such resources as men and equipment. Planning consists of breaking the project down into work elements and arranging these work elements into the diagram that becomes the working model of the project. As the work elements are defined, three questions are asked about each of them:

1. What immediately precedes this work element?
2. What immediately follows this work element?
3. What can be done simultaneously with this work element?

In developing the arrow diagram, an arrow is drawn for each work element. The tail of the arrow is connected to all of the work elements that must be completed immediately before the job under consideration can begin. The head of the arrow is connected to all of the jobs that cannot begin until the job being considered has been completed. The length of the arrow isn't important because it does not represent the duration of the job. In the example shown below, job A must be completed before any other job can start. When job A has been completed, jobs B and D can start. Job E can begin when job D ends. When job B has been completed, jobs F and C can begin. Jobs E, C, and F must be finished before the job G can commence. Finally, job H can begin when job G is finished.



To take an example, suppose that the project consists of constructing an underground duct system from one existing manhole to another existing manhole. Study of the project shows that it breaks down into the following work elements.

1. Site survey
2. Trenching
3. Duct laying
4. Pour concrete envelopment
5. Make manhole connections
6. Back fill trench
7. Clean up site and final grading.

Obviously we have to know where the duct system will be placed so the site survey is done before the trenching can begin. Therefore we draw an arrow from left to right and label it "site survey," (see fig. 3-7). When the trenching is done we can lay in our duct. For each work element we draw an arrow. The final arrow represents clean up and final grading.

PARALLEL WORK ELEMENTS

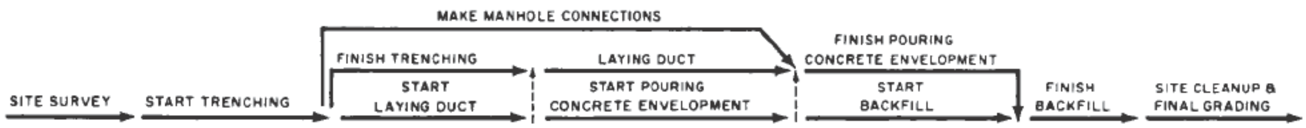
The work that can be done simultaneously with other work is called parallel work elements. Sometimes in order to show this, it is necessary to break up some of the arrows into two or more parts; for example, an underground duct between manhole A and B. First the site survey is made; then the trench is prepared; then the duct is laid making manhole connections. Finally, the trench is backfilled. However, it is obvious that in this type of work it is NOT necessary that one job be completely finished before another is begun. As soon as enough trenching is done, duct laying may begin, and so forth, until we may well have several work elements going on concurrently. No job in this example may be completed, however, until the job preceding it has been completed. For example, the concrete envelopment cannot be finished until the duct laying and manhole connections have been done. In a situation like this, we need two arrows for each work element—one to show the start of the job, and one to show the end of the job. See figure 3-8.

EVENTS AND EVENT NUMBERING

Events are the points at which arrows connect to one another—points in time marking the completion of some work and the beginning of other work. Events are numbered from left to right through the diagram. The number of the event at the head of an arrow

26.178

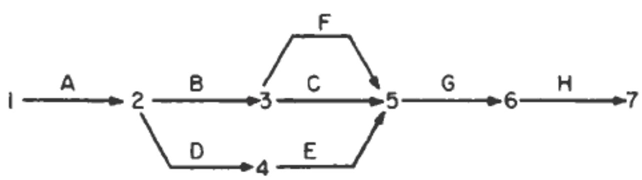
Figure 3-7.—Simplified arrow diagram.



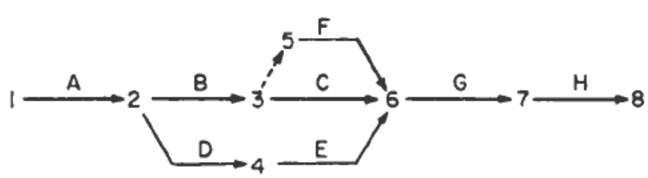
26.179

Figure 3-8.—Laying underground duct.

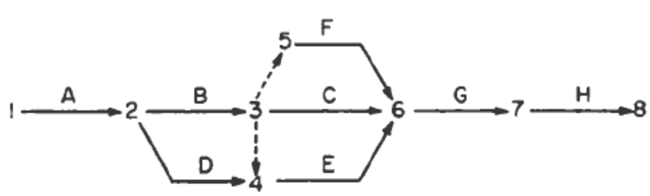
must always be greater than the number of the event at its tail. The events in the following example are numbered correctly.



The event numbers are used to identify the work elements. Job B is known as work element or job (2, 3). Because there are times when two work elements will have the same numbers; the solution is to use a dummy arrow and renumber the remainder of the diagram as shown below.



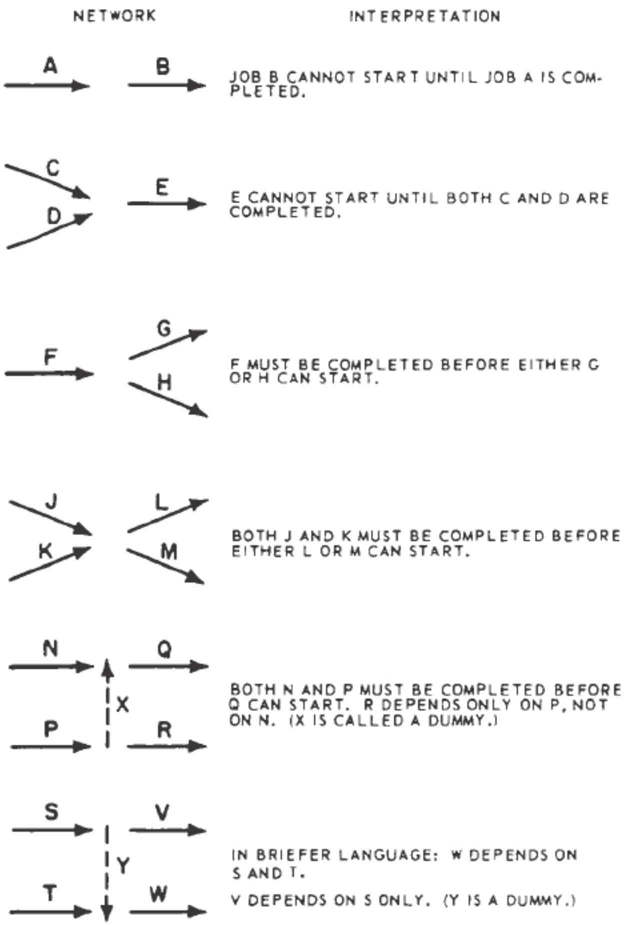
Dummy arrows also are used to clarify the interdependency of jobs, as shown below. Dummy (3, 4) shows that job E cannot begin until jobs B and D have been completed.



Dummies are also used to show conditions that are not really part of the project but on which the ability to begin the job depends. Suppose that before work on ditch digging can begin a machine has to be obtained. Acquiring the machine is project work that must be scheduled, but the arrival of the ditch digger on site is not project work but, rather, a condition necessary to the beginning of the work. Therefore a dummy arrow is inserted in the diagram to represent this delivery. Dummies like this are generally called restraints. In actual practice, the events would not be numbered until after the diagram is completed.

FINAL CHECK OF DIAGRAM

The completion of the arrow diagram completes the planning stage of planning and scheduling. A word of caution: If you don't know the sequence of work, find out before you complete the diagram. Before you assign event numbers to your diagram, go over it carefully and make sure that the work sequence is correct and that all dummies and restraints are shown. Examine it for superfluous dummies which only confuse the diagram and add to the work of updating it. If you are not thoroughly familiar with the sequence of work before you started the diagram, you will find that the necessity for analyzing the project step-by-step has much improved your understanding of it. Basic rules for arrow diagramming are summarized in figure 3-9.



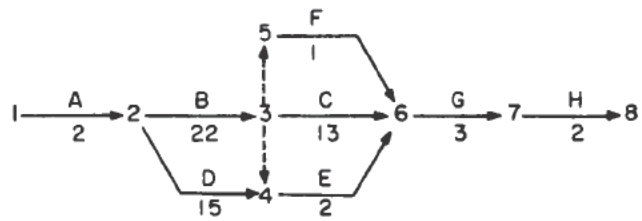
26.180

Figure 3-9.—Elements of network diagramming.

WORK ELEMENT DURATIONS

We have learned how a project is planned; now the next step is to schedule the operation, or to put it on a working timetable. When this has been done we will know when each job must be performed, when deliveries must take place, the spare time on each job, and when the whole operation is to be finished. We will also know which jobs are critical, and to what extent a delay in one job will affect others following it.

The first thing we must know in scheduling an operation is how long each work element should take under normal circumstances. This normal job duration is estimated on the basis of previous experience (construction norms). If it is a new project which has not been attempted before, the job durations are estimated by careful analysis of the work to be done. No matter what scheduling method is used, if the input information is unrealistic the results will be unrealistic. You must remember to take care in obtaining sound estimates based on logical reasoning. Job durations are marked on the arrow diagram alongside the corresponding job arrows as shown below. They may be expressed in hours, days, weeks, or months, but the unit of measurement must be consistent throughout. Dummies used to give a job separate identity or job interdependencies have zero project duration, while dummies representing restraints as deliveries will have duration time associated with them.

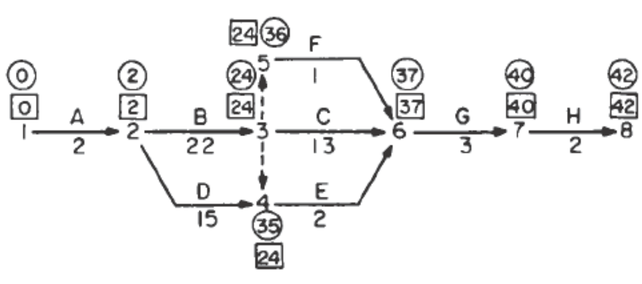


The project duration is the longest path in terms of time through the diagram. The critical path in figure 3-E runs as follows:

Event Numbers	Duration (days)
1-2	2
2-3	22
3-6	13
6-7	3
7-8	2
	42

Every work element on this path is critical to the completion of the project in 42 days. Once the critical path is determined, it is advisable to examine the work elements more closely to see whether by breaking them down further the project duration can be shortened.

The earliest event time is entered in a box next to the event. For example:



Event 1 marks the beginning of the project and occurs at project time 0. The duration of job (1, 2) is 2, so event 2 occurs at project time 2. Event 3 occurs at project time 24, because the duration of job (2, 3) is 22. Event 4 has two arrows leading into it, so both paths must be examined.

$$(1,\ 2) + (2,\ 3) + (3,\ 4) = 2 + 22 + 0 = 24$$
$$(1,\ 2) + (2,\ 4) = 2 + 15 = 17$$

The earliest time at which 4 can occur is 24. In figuring event 6, the earliest it can occur is 37. In practice, the earliest event time is determined by adding the duration of the arrow in question to the preceding earliest event time. When there are more than one arrow leading into an event, all possible earliest event times must be calculated in order to determine the true earliest event time. The true earliest event time is the largest of the results obtained.

It is also necessary to know the latest time an event can occur. To determine latest event times, you begin at the end of the project and work backward. To calculate the latest event time you subtract the duration of the immediately following job from the immediately following latest event time. Looking at the figure above you will find the latest time event 8 is 42 and event 7 is 40. When an event like event 3 has more than one arrow leaving it, you calculate all of the latest events in order to determine the latest time at which the event can occur. The latest event time is the smallest of the results obtained. We know that there are three conditions that must be met for a job to be critical. They are:

1. The numbers in the box and circle at the head of the arrow must be identical.

2. That numbers in the box and the circle at the tail of the arrow must be identical.

3. The duration of the job must be equal to the time available for its completion. Therefore, their earliest and latest start times are identical, as is their earliest and latest finish times.

RULES FOR CALCULATING

Having established the earliest and latest event times, we have another step to determine—the earliest and latest starts and finishes for the work elements. After you have made your diagram of a project and you have your event times, you can determine the start and finish times by using these four basic rules:

Earliest start day = earliest event time at the tail of the arrow +1

Earliest finish day = earliest event time at the tail of the job + job duration

Latest start day = latest event time at the head of the arrow - job duration +1

Latest finish day = latest event time at the head of the arrow.

To calculate earliest finish days, you work from left to right on the diagram, adding job durations to earliest event times. To calculate latest start times, you work from right to left, subtracting the job durations from the preceding latest event time.

There will be jobs that can start at an event and not be required to be complete for several events later. The time to do the job may only be 2 days and you have spanned 12 days before the completion is required. The spare time available to perform the job is called FLOAT. Properly controlled, the manipulation of float is valuable in determining the most efficient use of manpower, machinery, and materials.

FEEDBACK

A feedback system must be established to provide the operations officer with changed information and current work progress. As a project proceeds, it may be discovered that the original estimates were not accurate, or that a delivery cannot be made on time, or that the men will not be available as originally planned. There may be design changes that could lead to the addition of new jobs, or the canceling of some jobs. Sometimes it may be necessary to make a more detailed breakdown on the arrow diagram. Such changes could result in a shift of the critical path, or in new target dates, or they may make it necessary to expedite certain parts of the project in order to keep on schedule. The information

the crew leaders feedback (via project chain of command) in their reports may well be the reason for changes that are necessary. They should report regularly on current work in progress, and the report should include such information as:

The completion date of each job.

The beginning date of each job.

Significant delays of current jobs.

Estimated number of man-days required to complete current jobs.

This information enables the operations officer to spot trouble areas immediately and to take corrective action.

CHAPTER 4

PROTECTIVE DEVICES AND CONTROLLERS

Protective devices and controllers are standard equipment for all electrical systems. Operating, servicing, or troubleshooting controllers and protective devices range from simple tasks such as changing a fuse to complex jobs such as determining whether an automatic voltage regulator is operating properly. These and many other jobs are necessary if proper electrical service is to be maintained within an electrical system.

PROTECTIVE DEVICES

The function of any protective device is to protect life and equipment. Generally speaking, protective equipment is designed to interrupt the flow of electricity in a circuit when operating conditions become dangerous. Fuses and circuit breakers are the main types of electrical protective devices.

FUSES

As you know, the simplest overload protective device is a fuse. The principle of fuse operation and a few common types of fuses are described in Basic Electricity, NavPers 10086-A, and in Construction Electrician 3 & 2, NavPers 10636-E. In this chapter, we shall discuss other types of fuses.

High-Voltage Fuses

High-voltage fuses are used at substations to provide back-up protection for the low-voltage feeder breaker and to prevent a transmission line outage on faults occurring within the substation ahead of the low-voltage breaker or feeder fuses.

For substations up to the 69-kv class having transformer capacity limited to 5,000 kva or less, fuses combined with gang-operated airbreak switches are safe and reliable and may be used for transformer protection. The cost of installing and maintaining fuses and airbreak switches is less than comparable costs for oil circuit breakers. The added maintenance cost of replacing fuses is more than recovered in reduction of costs chargeable to inspection and maintenance of oil circuit breakers, relays, and battery control circuits. One disadvantage of fuses is that they may single phase. This may cause partial or total interruption of service. There is no possibility of single phasing with an oil circuit breaker.

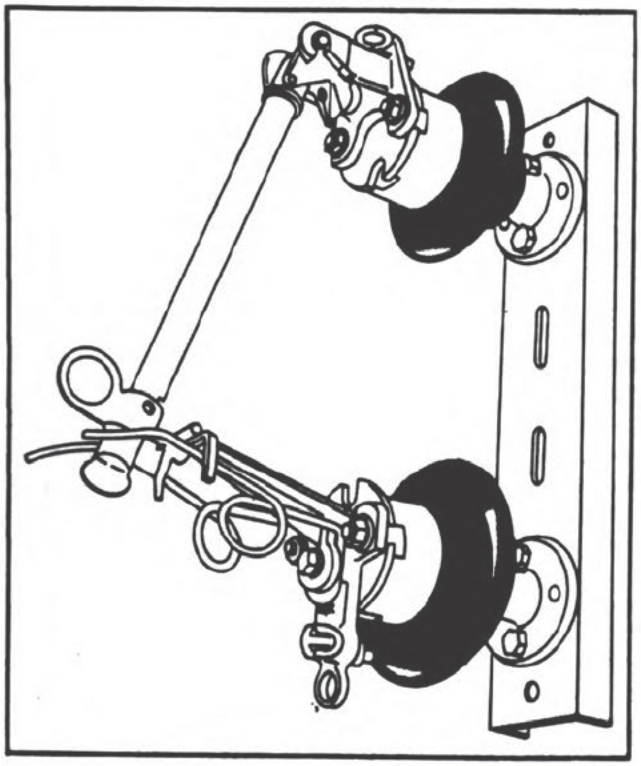
When re-fusing gang-operated airbreak switches, greater safety is ensured with the installation of a gang-operated grounding device that grounds both side of the fuse. If such a device is not warranted, ordinary ground sticks should be accessible for use at all times. A fusing platform may be used to enable the operator to replace fuses that are mounted too high in the structure or too close to high-voltage equipment for safe fuse-stick operation from the ground.

Expulsion Type Fuse

The expulsion fuse shown in figure 4-1 is an open cutout or disconnect fuse. It has a universial tension type fuse link. When the fuse link melts, current is made to flow through the thin stranded wire. The current instantly melts the wire and removes tension on the spring thereby causing the fuse terminal to separate.

Repeating Cutout Fuse

The repeating cutout fuse shown in figure 4-2, has three fuse tubes mounted so that when the first fuse "blows," it trips the second fuse into the circuit. If the fault continues the second fuse trips in the third. This arrangement



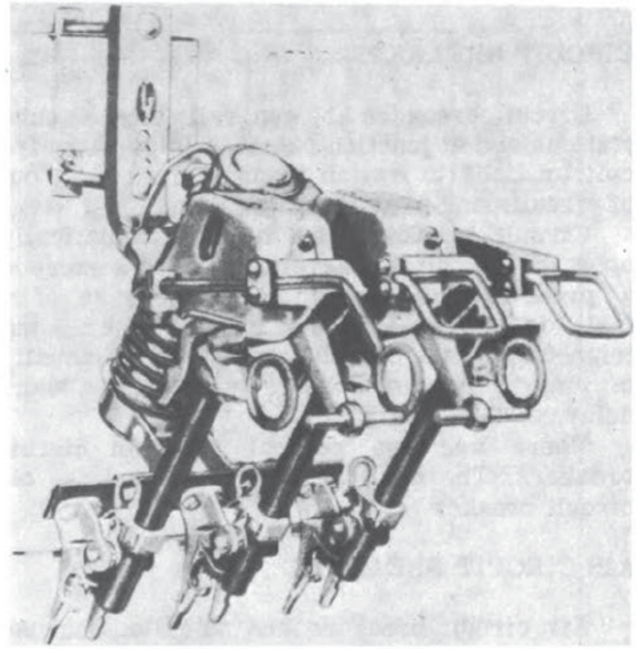
26.7
Figure 4-1.—Outdoor open type cutout fuse (expulsion) 7,500 volts, 100 amperes.

allows clearance of temporary faults and promptly restores service by the automatic circuit reclosing action of the second and third fuse if necessary. This type of fuse assembly is almost exclusively applied in outdoor distribution circuits.

Other Fuses

Other types of fuses are the BORIC ACID FUSES, LIQUID FUSES, and DRY TYPE CURRENT-LIMITING FUSES. In the boric acid fuse, a malfunction in the circuit produces steam which interrupts the flow of current. This type of fuse can be mounted with small clearances; there is no visual indication that the boric acid fuse has blown.

One common form of liquid fuse is the oil-filled cutout, in which the fusible element is submerged in oil and is generally mounted on a circulating or rotating frame so that by moving an external handle the circuit can be interrupted. This type of fuse is generally used in underground systems.



26.8
Figure 4-2.—Automatic reset repeating cutout, 15,000 volts, 100 amperes.

There are two kinds of dry type current-limiting fuses: the single and the double element type. These fuses operate on the principle of melting the fuse far in advance of the possible peak current of the first half-cycle. The fuse is designed in such a manner that the melting process introduces a high arc resistance, which, in turn holds the circuit current within the rating of the fuse.

FUSE MAINTENANCE

Fuse maintenance consists of inspecting mountings and supports, and checking for broken insulators and mechanical defects. Replace without delay broken or cracked insulators and repair or replace, as necessary, parts that are defective. Routine inspections should always include:

1. Checking fuses for correct rating and ensuring that fuse tubes are capped securely to exclude dust and water.

2. Replacing warped, broken, scorched, or burned tubes.

3. Keeping fuses with dropout and repeating features in good condition and free from foreign matter. Check them for proper operation by trial on routine fuse changes, or

when the transformer bank is deenergized for other purposes.

CIRCUIT BREAKERS

Circuit breakers are generally used at substations and at junction points of important circuit or lines to switch transformers in or out of circuits and to sectionalize lines.

Circuit breakers like fuses, automatically open the circuit whenever the current exceeds a predetermined value, either because of a fault or overload in the circuit. After being tripped open, the circuit may be closed manually or may be automatically reclosed after a short delay.

There are two general types of circuit breakers. The air circuit breaker and the oil circuit breaker.

AIR CIRCUIT BREAKERS

Air circuit breakers are so called because the main contacts open in the air. Air circuit breakers are normally used on switchboards, switchgear groups, and distribution panel. They are seldom, if ever, used on distribution lines. When operated electrically, the operation is usually in conjunction with a pilot device such as a pressure switch. Electrically operated circuit breakers employ an electromagnet, used as a solenoid, to trip a release mechanism that causes the breaker contacts to open. The energy to open the breaker is derived from a coiled spring. The electromagnet is controlled by the contacts of the pilot device.

Circuit breakers designed for high currents have a double-contact arrangement. The complete contact assembly consists of the main bridging contacts and the arcing contacts. All current carrying contacts are high-conductivity, arc-resisting silver or silver alloy inserts.

Each contact assembly has a means of holding the arcing to a minimum and extinguishing the arc as soon as possible. The arc control section is called an arc chute or arc runner. The contacts are arranged so that when the circuit is closed, the arcing contacts close first. Proper pressure is maintained by springs to ensure that the arc contacts close first and that the main contacts follow.

When the circuit opens, the main contacts open first. The current then flows through the arc contacts; this prevents burning of the main contacts. When the arc contacts open, they pass under the front of the arc runner. This causes a magnetic field to be set up, which blows the arc up into the arc quencher and quickly opens the circuit.

OIL CIRCUIT BREAKERS

The typical oil circuit breaker consists of one or more metal tanks filled with insulating oil and metal caps attached to the top of the insulating bushings. Conductors or copper rods attached to stationary contacts located below the oil level in the tanks pass through the metal caps. The stationary contacts are bridged by movable contacts. The movable contacts are operated by an external or an internal source. When the breaker is closed, the movable contacts complete the circuit. When the circuit is open, they are displaced from the bridging position.

Installation

Circuit breakers are normally mounted and controlled in one of the following ways.

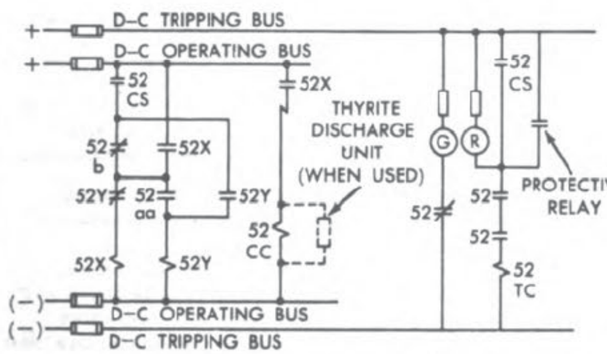
1. Directly on a switchboard with manual closing and opening and with automatic electrical training.
2. Remote from a switchboard with manual closing and opening and with automatic electrical tripping.
3. Remote from a switchboard with electrical closing and opening and with automatic electrical tripping.

Closing mechanisms are of the solenoid type, the centrifugal-motor type, or the pneumatic type.

Energy for opening and closing oil circuit breakers, operated manually or by automatic remote control, may be supplied from one or more of the sources shown by the control diagrams in figures 4-3, 4-4, and 4-5.

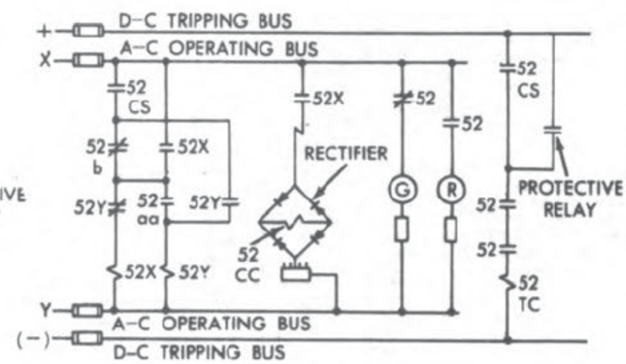
MAINTENANCE AND INSPECTION OF POWER CIRCUIT BREAKERS

Procedures for inspecting and overhauling oil circuit breakers depend largely on the nature of service and the type of apparatus used. Make inspections at least twice a year and oftener if necessary. Where a humid-tropical climate exists and a circuit breaker normally remains in an open or closed position over extended periods of time, operate it periodically for two or three



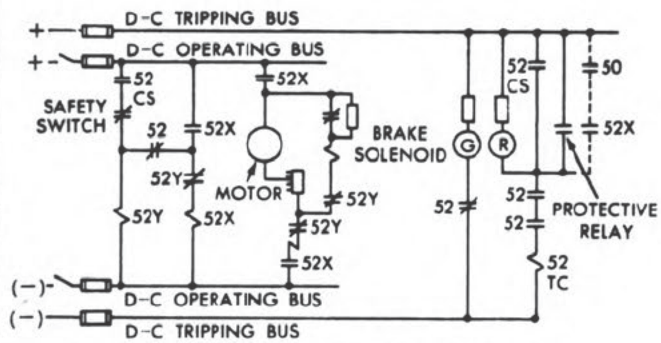
TYPICAL ELEMENTARY DIAGRAM OF D-C SOLENOID MECHANISMS

(A)



TYPICAL ELEMENTARY DIAGRAM FOR A-C RECTIFIER-SOLENOID MECHANISMS

(B)



TYPICAL ELEMENTARY DIAGRAM OF TYPE ME-10 MOTOR MECHANISMS FOR FH OIL-BLAST CIRCUIT BREAKERS

(C)

NOTES

1. CONVENTION HAS DEVELOPED, AND NEMA HAS STANDARDIZED, NUMBERS FOR SWITCHGEAR DEVICES, FOR CONVENIENCE OF REFERENCE. AUXILIARIES AND ATTACHMENTS ARE INDICATED BY LETTERS APPENDED TO THE DEVICE NUMBERS. THE FOLLOWING SYMBOLS, DEVICE NUMBERS, AND LETTERS ARE USED IN FIGURES (A), (B) AND (C).

2. FOR SIMPLICITY, TERMINAL BOARDS, AUXILIARY SWITCHES NOT CONNECTED IN THE CONTROL CIRCUITS, AND ALSO KNIFE SWITCHES USED IN THE CONTROL CIRCUITS OF MANY OF THE LARGE BREAKERS, ARE OMITTED FROM THE TYPICAL DIAGRAMS IN FIGURES 69 AND 70.

LEGEND

=CONTACT OPEN WHEN DEVICE IS OPEN, OR IN DEENERGIZED OR NONOPERATED POSITION.

=CONTACT CLOSED WHEN DEVICE IS OPEN, OR IN DEENERGIZED OR NONOPERATED POSITION.

=CONTACTS WITH BLOWOUT COIL.

=FUSE

=FIXED RESISTOR

=TAPPED RESISTOR

=GREEN INDICATING LAMP

=RED INDICATING LAMP

=COIL OR WINDING

50=SHORT-CIRCUIT SELECTIVE RELAY, USED WHEN THE RMS AMPERES IN FIRST CURRENT LOOP (FIRST CYCLE) OF SHORT CIRCUIT, DURING CLOSING OPERATION OF CIRCUIT BREAKER, MAY EXCEED THE MAXIMUM INTERRUPTING CURRENT OF THE BREAKER.

52=POWER CIRCUIT BREAKER (NOT SHOWN).

52X=CLOSING RELAY OR DEVICE FOR 52.

52Y=CUTOFF RELAY OR ANTIPUMP DEVICE FOR 52.

52CS=CONTROL SWITCH FOR 52.

52CC=CLOSING COIL FOR 52.

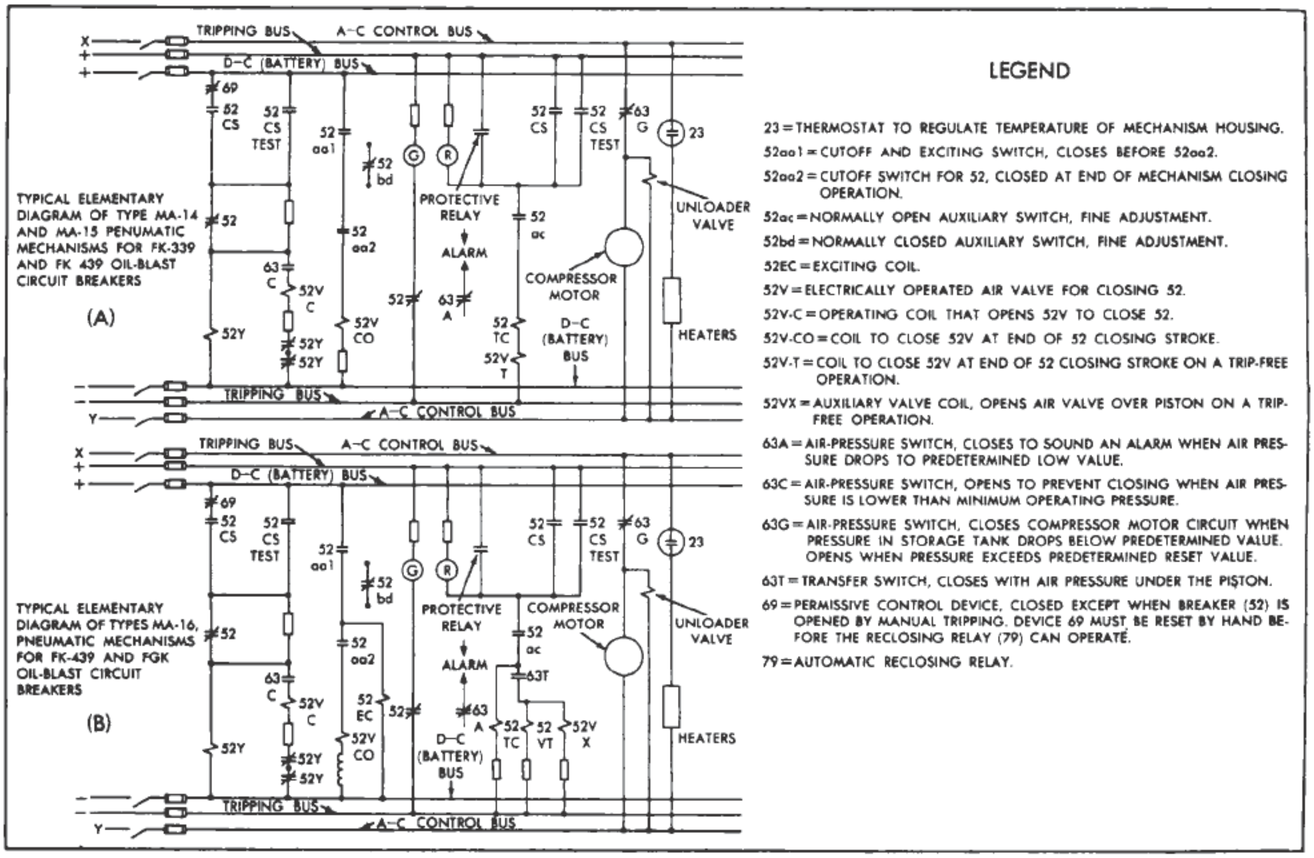
52TC=TRIP COIL FOR 52.

52aa=CUTOFF AUXILIARY SWITCH FOR 52, CLOSED AT END OF MECHANISM CLOSING OPERATION.

SAFETY SWITCH HOLDS OPEN THE CLOSING CIRCUIT WHEN MAINTENANCE CLOSING DEVICE IS IN PLACE

26.9

Figure 4-3.—Typical connection diagram of electrically operated oil circuit breakers.



26.10

Figure 4-4.—Typical connection diagrams for pneumatic mechanisms for outdoor oil blast power circuit breakers.

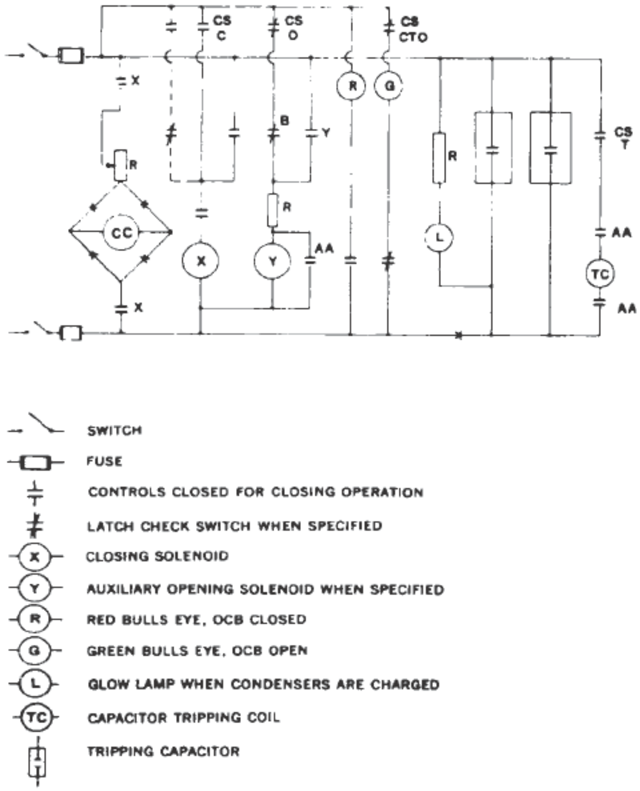
opening and closing cycles to make sure that parts are in working order and properly lubricated. Such tests can usually be made at times when intermittent interruptions of power will not interfere with normal operation; make them during periods of light load if the breaker is in normally closed service for extended periods. Make an inspection after a breaker has opened to clear a severe fault. OVERHAUL AT LEAST EVERY 2 YEARS, preferably in the spring of the year. Recommended procedures for making periodic overhauls are described in the following paragraphs.

Preliminary Procedure

Make arrangements in advance with the electrical superintendent to take apparatus out of service. After the breaker is opened, check for positive grounding. The man in charge of the crew must check to be sure the apparatus is deenergized and safe for personnel to handle. The disconnect switches should be opened to isolate the oil circuit breaker completely from any possible source of energy. If one or more potential transformers are used in connection with the oil circuit breaker and they are connected to the oil circuit breaker side of the disconnecting switches. The fuses on the primary side of these potential transformers should be removed. After this switching is completed, the proper tags are placed on the oil circuit breaker controls.

To prevent accidental contact by personnel, place suitable barriers around adjacent apparatus that might still be energized. In crowded installations, barriers may be of rope or net with suitable danger flags, or of temporary rigid insulated material.

Equipment to be worked on must first be deenergized, (both sides of the circuit broken),



26.11
Figure 4-5.—Typical connection diagram of capacitor trip, solenoid close oil circuit breakers.

then grounded. To perform these operations safely, personnel should always use:

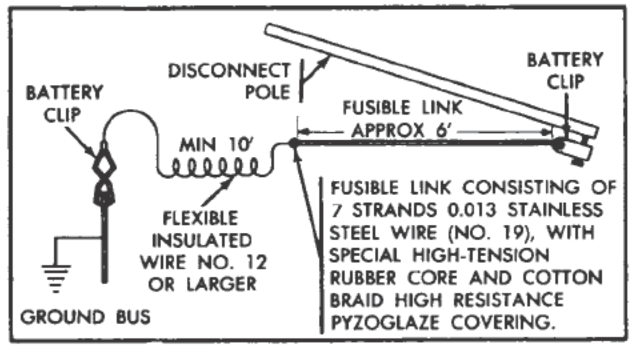
1. Rubber gloves

2. Safety goggles

3. An approved voltage detector. A voltage detector may be made from a length of insulated wire, equivalent to No. 12 wire or larger, with a 6-foot fusible link consisting of No. 19 special high-tension wire fastened to a disconnect pole. (See fig. 4-6.)

GROUNDING CABLE.—A No. 2, or larger grounding cable should have a suitable clamp on one end for making connection to a ground bus. On the other end hot-stick clamps should be provided for connection to metallic terminals of apparatus. (See fig. 4-7.)

Neither adjustments nor replacement of parts of circuit breakers should be attempted without first consulting the manufacter's instruction manual.



26.12
Figure 4-6.—Diagram of a voltage detector.

Testing and Grounding

The following is the recommended procedure for testing and grounding:

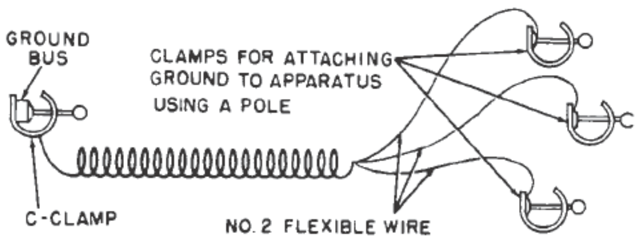
1. Connect one end of an insulated test wire to the ground bus and fasten the other end to the disconnect pole.

2. Wearing rubber gloves and goggles, touch each metallic terminal of the bushings with a test cord. After touch-testing the apparatus, remove the test wire.

Connect one end of each grounding cable to the ground bus, and apply the hot stick clamps on the other end of the cable to each metallic terminal of the bushings of the oil circuit breaker. Whenever a circuit or a piece of equipment is grounded out for the protection of personnel, some means must be provided for tagging the point of grounding so that other personnel will understand that the ground should not be removed until maintenance work is completed. Various means may be used. Brilliantly colored tags large enough to be seen from a considerable distance are suitable as are flags that may be hung or clipped to the equipment. Good maintenance practices prohibit the removal of switching or grounding tags without the knowledge and consent of the individual who placed them. This is a safety practice that must be rigidly adhered to.

Isolating Controls

To isolate the closing and tripping control and to prevent inadvertent operation of the oil circuit breaker, the switch in the operating control circuit must be opened. If there is no switch in the operating control circuit, block the closing relay in the open position and



26.13

Figure 4-7.—Grounding cable.

disconnect the trip coil from the circuit, thus making the oil circuit breaker inoperative from any remote control station.

Lowering and Removing Tanks

Place a pan under the breaker before lowering the tank, to catch any oil spill. Larger breakers usually have tank lifters for lowering the tanks; on smaller breakers, the tanks are lowered by hand. When using a tank lifter, take some tension on the lifting cables or platform to take the load off the bolts while they are being removed. Then remove the tank bolts and lower the tank to the pan on the floor or pad. When the tanks been lowered, the following routine is recommended: Allow the mechanisms to drain for a few minutes before removing the tanks, and operate the breaker by hand to force oil out of the contacts. Do not trip free unless the contact mechanism is immersed in oil; this prevents injury to buffer springs, insulators, and so on. Release the breaker and let it out slowly by the hand-operating lever. After this has been done, wipe the interiors of the mechanisms dry with lint-free wiping rags. Then remove the tanks from beneath the breaker and filter the oil.

Tank Liners

The next step is to drain the tanks and remove the liners. Clean the tanks and liners with lint-free rags. If the liners are of the paper-composition type, check them carefully for moisture. Although paper liners do not absorb oil, they readily absorb any water that gets into the oil and ultimately cause the liners to separate and become soft and pliable. If a liner contains moisture, dry it in an oven before replacing it in the tank. If a liner has a metal ring around the top, check the bonding between the metal ring and tank. The ring must make positive contact with the tank metal.

Inspection of Contacts

Check contacts and arc tips for burning, mechanical defects, and so on. Although the main contacts should not show signs of burning, an arc sometimes carries over from the arc tips to the main contacts during a violent tripout. Check to see that breaker contacts are properly aligned and that contact surfaces bear against one another, with uniform, firm pressure and are adjusted in accordance with the instruction book. Replace badly pitted or burnt-out contacts, but smooth down with a clean fine file those that are only roughened. (This does not apply to silver contacts.) When a device contains both main and arcing contacts, the main contacts require little maintenance, but should be inspected regularly and kept smooth and clean.

Replace arcing contacts if they are badly pitted or burned or when their dimensions fall below minimum requirements. This will assure their continuing to protect the main contacts from arc damage. Finger-type contacts normally require more maintenance than butt contacts. An indication of excessive arcing is the decrease in thickness of the contact metal below the minimum thickness required for proper operation as stated in the instruction book. Most manufacturers state the minimum thickness of metal required for proper operation. Although some adjustment is provided, there are limitations beyond which operation will not be satisfactory.

Contacts on interrupters, such as those used on certain oil-blast breakers, require proper alignment and uniform pressure.

Radial-blast interrupters and cross-blast interrupters use butt contacts, with their arcing and current-carrying functions being performed by the same set of contacts. These are high-pressure type interrupters, and it is not necessary to dress or smooth their contact surfaces. However, such contacts are gradually burned away by arcing and must be adjusted at intervals and replaced eventually to maintain proper contact. Approximately three-thirty seconds (3/32") of an inch can be burned off the upper and intermediate contacts before they demand replacement. The contact rod tip can be burned off to a stub too short to make contact without encroaching on required clearance between the bottom of the interrupter and the contact crossarm.

The main contacts of cross-blast interrupters require little attention except periodic checks for proper alignment and adjustment and to assure that they are kept smooth and clean.

Replace arcing contacts as in any other interrupting device when they become badly pitted or burned. Keep the contacts of magnetic air-blast breakers clean and bearing with uniform pressure in the same way as other contact surfaces. When proper contacts cannot be maintained, or the alloy turns back far enough so that the arc is destroying the copper, replace the contacts. In air-blast breakers, make periodic inspections to ascertain that no excessive wearing or scoring has taken place on the surfaces of the wiping contacts. If they are badly scored or pitted, replace them. A good indication of the condition of the contacts within the arc chute can be made by inspecting the arcing tips on the moving contact blades. If these are badly pitted or burned, it is probable that the internal contacts are in the same condition. Severely burned contacts or fibers in the chute indicate need of replacement.

Oil

Test oil in service at frequent intervals (3-month intervals are recommended) or after each operation at or near breaker rating. If oil shows sign of moisture, carbonization, or dirt, filter and test it with a standard spark gap oil tester. If the dielectric strength of the oil tests less than 22,000 volts as measured by standard disks in the tester spaced 0.1 inch apart, keep filtering the oil until the proper dielectric strength is reached. The dielectric strength of new oil should be 26,000 volts minimum. Keep the oil in the tanks at the proper level, and check the oil gage to make certain that it is indicating properly. Check all oil valves to see that they do not leak. Also, check the condition of all gaskets to make sure that they seal properly to prevent entrance of moisture and leakage of oil.

Bushings

Clean the external surfaces of bushings to remove dirt or other deposits. Where abnormal conditions prevail, clean bushings frequently to reduce possibility of flashover. Warm water and soap are recommended for cleaning most bushings; if soap is not available, an approved Navy solvent may be used; take care to avoid spilling the solvent on parts that could be injured by it. Check the bushings to make sure that they have not moved from the proper positions on account of vibration or other causes. Check porcelains for cracks or breakage, and note the level of oil in oil-filled bushings to make sure that it is at the proper level.

Internal Insulating Parts

Clean all surfaces of the bushings and other insulating parts inside the tanks to remove traces of carbon or sludge that may remain after the tanks have been drained. Clean all internal parts of breakers before new filtered oil is added.

Keep insulating parts of magnetic air-blast breakers clean and dry. Wipe off dust, carbon, or other foreign matter collected on magnetic air-blast breakers between inspection periods and, if there is evidence of dampness, install heaters in the compartment to ensure dryness. Scale that develops on the insides of arc chutes should be left intact, but loose scale in the muffler portions of the devices should be cleaned out to prevent malfunction of the arc.

Porcelain air-line insulators (if any) in the rear of the arc chutes in air circuit breakers should be wiped out and inspected for mechanical damage. Remove these insulators at least once a year and inspect for damage; then clean them internally with suitable solvents. Remove any accumulation of carbon or dirt.

Breaker Mechanism

The breaker mechanism should operate smoothly and freely without stiffness or binding. Lubricate all bearing surfaces with the lubricant recommended by the manufacturer of the circuit breaker. Ascertain that all cotter pins have been opened after insertion and that all snap rings, locking plates, nuts, and so on are in place and properly tightened. Check the stop clearance against the value given in the instruction book and adjust it if necessary. Inspect oil-filled dashpots and fill them with the same type and grade of oil as specified for the breakers with which they are used. The length of the breaker stroke and its opening and closing speeds should be measured, checked and adjusted in accordance with directions contained in the instruction book. Make certain that the operating rod for moving the contacts does not bind against its guide. Check also for broken or distorted springs.

Operating Mechanism

Lubricate the mechanism in accordance with the instruction book and see that it operates freely throughout its entire stroke. Make parts that are scored or show excessive wear conform to tolerances listed in the instruction book. Ensure that the operating voltage at the mechanism terminals, with full operating current flowing, is adequate for correct operation. This is especially important for solenoid-operated mechanisms. Check the air pressure on pneumatically operated mechanisms to assure that it is adequate and that it is restored promptly after each breaker operation. Inspect air connections or piping for possible leaks and broken or distorted springs. In addition, make the following routine checks:

1. Closing relay and its contacts.
2. Tripping arrangement for positive tripping, including auxiliary switch adjustments and contacts. Dress or replace damaged contacts.
3. Pneumatically operated mechanisms. Check all electrically operated valves; keep the air system clean by periodic replacement of compressor filter pads, by regular blowing off of water condensation, and by systematic overhaul and cleaning of the air strainer, check valve, unloader, and other critical parts that collect dirt. Check the adjustment of all pressure switches and lockout devices. Refer to the instruction book for proper pressures.

Check all cotter pins, locking plates, snap rings, and nuts for tightness.

Auxiliary Equipment on Mechanism

The operating mechanism on an oil circuit breaker employs an auxiliary multiple-pole switch for making-and-breaking, closing, tripping, and position-indicating circuits. The following is the recommended inspection procedure.

1. Check all auxiliary switch contacts to see that they operate freely and make good contact. Burns sometimes occur on heavily loaded contacts, such as those for large trip coils. In such cases, remove relays if necessary to clean the contacts with fine sandpaper.

2. Check all electrical connections to the breaker mechanism and auxiliaries to see that they are tight and making good contact. Check and clean contacts and arc chutes on the auxiliary closing relay for operating the closing coil. Inspect and oil all bearings.

3. In the case of a motor-operated mechanism, inspect all electrical connections, motor bearings, and brushes, as well as all other moving parts. The speed of the closing motor is usually controlled by a variable resistor that is in series with the motor and can be adjusted for seasonal climatic changes or for adaption to a larger or smaller circuit breaker. For further information, refer to manufacturer's instruction manual.

Troubleshooting

Table 4-1 shows the common troubles encountered in power circuit breakers and gives the causes and remedies of each.

CONTROLLERS

A controller regulates the operation of electrical equipment. A controller for electric motors is simply a starter which provides a convenient and safe means of perming several or all of the following functions:

1. Start and stop
2. Accelerate and decelerate
3. Regulate the speed
4. Reverse

In some applications the motor must be frequently started, stopped, and reversed, in addition to having its speed varied continually. Some a-c motors controllers stop quickly by plugging. Plugging is the interchanging (by relays) of any two leads of a 3-phase motor to reverse the direction of rotation of the a-c field with respect to that of the rotor.

Motors up to 1 horsepower (hp) can usually be started or stopped by closing or opening a switch that connects the motor directly to the power source. To provide automatic protection against overload, fuses or circuit breakers are to be used. Circuit breakers may be incorporated in the design of the main switch. Motors rated from 1/20 to 1 hp, are sometimes furnished with the so-called sentinel breaker. The sentinel breaker is a small combination switch and circuit breaker containing a bimetallic thermal element. This thermal element will not trip immediately when an overload occurs; however, if there is a sustained heavy load the breaker will trip before the motor is damaged.

Some of the most common types of controllers used with a-c motors are:

Across-the line starters
Primary resistance starters

Table 4-1.—Troubleshooting Chart for Power Circuit Breakers

Trouble	Cause	Remedy
Overheating	Poor condition of contacts:	
	1. Out of proper alignment and adjustment.	1. Contacts should be lined up and adjusted properly.
	2. Burned and pitted because of lack of attention after many heavy operations, or too frequent operation.	2. Burned and pitted contacts (other than silver) should be dressed up, if practical, or replaced with new parts. (High-pressure butt-type contacts usually do not require dressing). Silver-to-silver contacts are very rarely dressed.
	3. Breaker kept closed (or open) for too long a period (copper contacts).	3. Operate breaker more frequently to wipe contacts clean. It may be advisable to consider the installation of new silver-to-silver contacts. The manufacturer's nearest office should be consulted.
	4. Overloading (continuous of prolonged current in excess of breaker rating).	4. If the breaker is overheating because of excess current, one of two remedies can be followed. a. replace with breaker having adequate rating for the present or future load; b. arrange circuits so as to remove the excess load.
	5. Transmission of heat to the breakers from overheated or inadequate cables or connection bars.	5. If the bars or cables overheat because of current in excess of their capacity, this can be remedied by increasing the carrying capacity (that is, increasing the size or number conductors) or by removing the excess current from the circuit.
	6. Loose connections or terminal connectors.	6. Tighten.
		7. Relocate in a cooler place, or arrange some means of cooling.
Failure to trip	1. Mechanism binding or sticking. Caused by lack of lubrication or mechanism out of adjustment.	1. Lubricate mechanism. Adjust all mechanical devices, such as toggles, stops, buffers, and opening springs, according to instruction book.
	2. Failure of latching device.	2. Examine surface of latch. If worn or corroded, replace. Check latch wipe, and adjust according to instruction book.
	3. Damaged trip coil.	3. Replace damaged coil.
	4. Blown fuse in control circuit (where trip coils are potential type).	4. Replace blown fuse.
	5. Faulty connections (loose or broken wire) in trip circuit.	5. Repair faulty wiring. See that all binding screws are tight.

Table 4-1.—Troubleshooting Chart for power Circuit Breakers—(Continued)

Trouble	Cause	Remedy
Failure to trip—(continued)	6. Damaged or dirty contacts on tripping device.	6. Dress or replace damaged contacts or clean dirty contacts.
Failure to close or to latch closed	1. Mechanism binding or sticking because of lack of lubrication or improper adjustment of breaker mechanism.	1. Lubricate mechanism. Adjust all mechanical devices, such as toggles, stops, buffers, and opening springs, to specifications in breaker instruction book.
	2. Burnout of operating (closing) coil (of electrically operated breakers) caused by operator holding control switch closed too long.	2. Replace damaged coil and teach operator how to operate properly. A better remedy would be to change the connections to include an auxiliary switch, which automatically cuts off the closing coil as soon as the breaker closes.
	3. Closing relay sticking.	3. Check or adjust closing relay.
	4. Cutoff switch operating too soon.	4. Adjust operation of cutoff switch to delay cutoff so as to allow breaker to close fully.
	5. Cutoff switch operating too late, causing the breaker to bounce open.	5. Readjust to reduce power at end of stroke and eliminate bounce.
	6. Insufficient control voltage (of electrically operated breaker) caused by:	6.
	a. Too much drop in leads.	a. Install larger wires; improve contact at connections.
	b. On. a-c control—poor regulation.	b. Install larger control transformer. Check rectifier, and be sure it is delivering adequate d-c voltage from adequate a-c supply.
	c. On d-c control—battery not fully charged or in poor condition.	c. Give battery a sustaining charge, or repair according to instructions in battery manufacturer's manual.
	7. Blown fuse in control circuits, faulty connection or broken wire in control circuit, damaged or dirty contacts in control switch (electrically operated breaker).	7. Replace blown fuse; repair faulty connection or broken wire; dress or replace damaged contacts in control switch.
Insufficient oil (in oil-circuit-breaker tanks)	Leakage of oil. Oil throw during operation.	Locate point of leakage, and repair. Tighten joints in oil lines. Fill oil tanks to proper oil level. (Modern G-2 oil-blast breakers do not throw oil when interrupting current within their rating.)
Dirty oil (in oil-circuit-breaker tanks)	Carbonization from any operations.	Drain poor oil and filter or replace with new oil. Clean inside of tank and all internal parts of breaker.

Table 4-1.—Troubleshooting Chart for Power Circuit Breakers—(Continued)

Trouble	Cause	Remedy
Moisture present in oil	1. Condensation of moist atmosphere. 2. Entrance of water from rain or other source.	1. Drain and filter oil or put in new oil. 2. Repair source of water entrance.
Sludging of oil	Overheating.	Filter or put in new oil. Remove source of overheating.
Gaskets leaking	Improper installation of gaskets at a previous inspection or repair. Oil saturation.	Put in new gaskets, treated in accordance with breaker instruction book.
Insulation failure	Absorption of moisture and accumulation of dirt, grim, carbon, and the like on bushing and insulating parts.	Thoroughly clean all insulated parts. Bake or dry out water-soaked parts (or treat in accordance with directions in breaker instruction book).

Secondary resistance starters
Autotransformer or compensator starter
Star delta starter

Regardless of the type of controller, all of them have overload protection devices, and most of them give low-voltage protection or low-voltage release protection. Many controllers are designed to withstand high mechanical shock and are equipped with manual latches or automatic latching relays to prevent false operation. Some typical controllers and wiring diagrams are shown in this chapter. A thorough knowledge of controller circuits and their operating characteristics will help you to install, maintain, and repair a-c controllers.

MAGNETIC ACROSS-THE-LINE STARTERS

A single-phase push button magnetic across-the-line starter connection is illustrated in figure 4-8. Both line leads are connected to the motor terminals through the main contacts M1 and M2, which close or open when the appropriate button is pushed. The thermal relay protecting the motor is connected in series with L2 in figure 4-8. A control circuit supplying the operating coil is connected across the main line. (The light line in fig. 4-8 is the control circuit; the heavy line is the main circuit.)

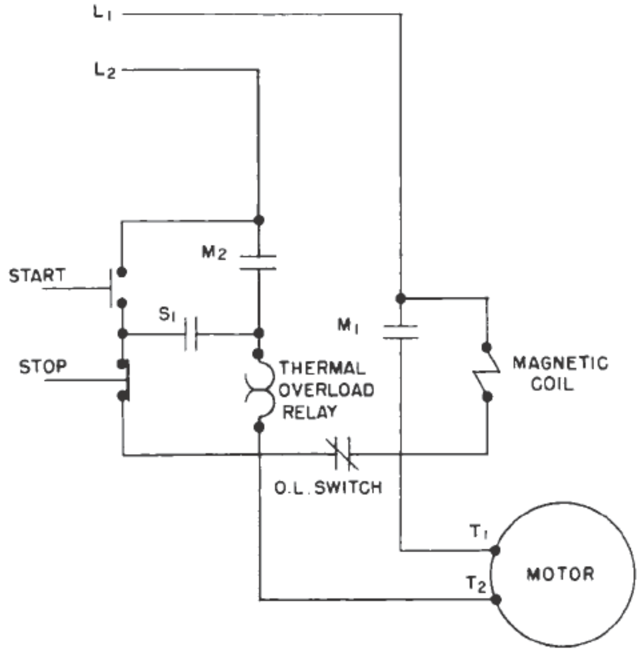
The magnetic coil circuit can be opened either by pressing the STOP button, or by operation of the thermal overload relay. Both of these actions deenergize the magnetic coil and open contacts M1, M2 and S1.

When the START button is depressed, the control circuit is connected across the line. The electromagnet is energized and closes the main contacts M1, M2 which connect the motor across the line. The holding contact S1 is also closed by the electromagnet and remains closed after release of the START button to keep the magnet coil energized.

Illustrated in figure 4-9 is a line diagram of a 3-phase magnetic across-the-line starter. The 3-phase magnetic across-the-line controller operates on the same principle as the single-phase unit except there are three line leads connected to the motor; also notice in figure 4-9 that the motor protecting thermal overload relay heaters are in series with L1 and L2 to the motor. Normally only two thermal overload relays are required to adequately protect the 3-phase motor.

When the START button is depressed, a circuit is completed from L1 through the START and STOP buttons and the coil of latching relay (LR) to L2. The coil of LR is energized and LR operates to close relay contacts C1 and C2. This action completes a circuit through coil M. Coil M is energized and closes the main line contacts M1, M2, and M3; this action connects the motor directly across the line.

The latching relay contact C1 completes the circuit to the coil of the main line contactor. Contacts C1 and C2 are mechanically connected by a lever which prevents them from opening as a result of a shock. Also, when the latching



26.14
Figure 4-8.—Line diagram of a single-phase magnetic across-the-line controller.

relay opens, it operates a mechanical latch which prevents the main contactor from closing while it is electrically deenergized.

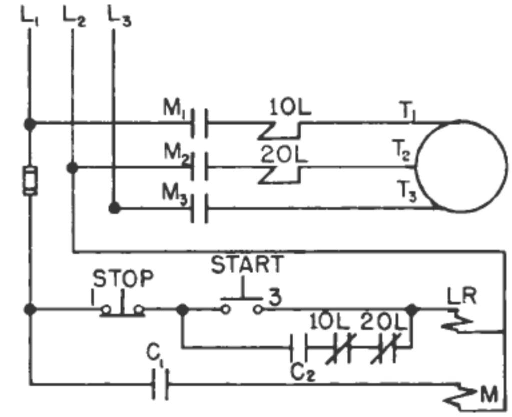
When the STOP button is depressed, the latching relay is deenergized and contacts C1 and C2 open. This deenergizes the coil of the main contactor and causes the main contacts to open.

You will notice that the overload relay contacts are in the control circuit, but are operated by heating elements placed in the main lines. The relays are reset by depressing the reset button. The control circuit is FUSED to protect the control circuit when remote control switches are used.

The starter also gives LOW-VOLTAGE PROTECTION by allowing the magnetic contactor to open when the line voltage fails or goes below a certain value. When the voltage is restored to its normal value, the motor will not start again until the START button is depressed.

PRIMARY RESISTOR CONTROLLER

Primary resistor starters are used on motors to reduce the sudden surge of current on starting, or when it is desirable to avoid



26.15
Figure 4-9.—Wiring diagram of a three-phase magnetic across-the-line starter with three-wire remote control.

sudden mechanical shock to the driven load. A typical line diagram of a magnetic primary resistor starter is illustrated in figure 4-10. Notice that the resistors are connected in the motor circuit.

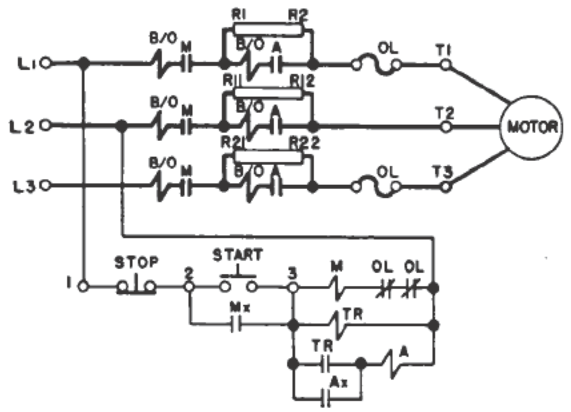
The two-point magnetic type starter is suitable for most applications. The two-point type starter is generally made up of an accelerator control, an overload relay, a timing relay, starting resistors, and a line contactor.

In operation the line contactor (M) is first to make contact, energizing the motor through the starting resistors. Then the time relay is activated after a predetermined time interval, closing the accelerating contactor (A), and cutting out the starting resistance, thereby placing the motor directly across the line. The motor now runs at full speed because all resistance has been cut out.

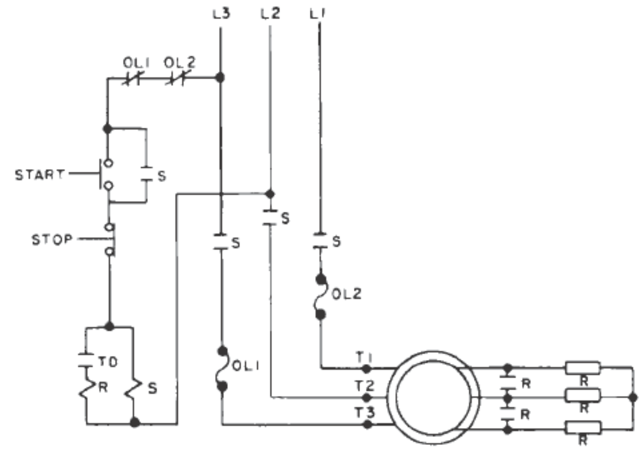
SECONDARY RESISTOR CONTROLLER

The magnetic secondary resistor controller is used in conjunction with a wound rotor motor requiring automatic acceleration. This type of starter usually consists of primary contactors, starting duty resistors for the motor secondary, overlay relays, and the required number of timed-accelerating contactors.

In operation, depressing the starter button closes the main line contactors, placing the rotor in series with the resistors, and the stator directly across the line. The contacts of the timed accelerator progressively short out



26.16
Figure 4-10.—Typical schematic diagram of a two-point primary resistor starter.



26.17
Figure 4-11.—A line diagram of a typical secondary resistor starter.

the secondary resistance until the slip rings are short circuited, thereby bringing the motor up to full speed. A line diagram of the secondary resistor is shown in figure 4-11.

REDUCED VOLTAGE CONTROLLER

An autotransformer starter (fig. 4-12) reduces the voltage applied to the motor during the initial starting period. It is used advantageously where high starting line currents must be reduced (more than with resistor starters) or where the starting torque of the motor must be adjusted to meet the particular load requirement.

One advantage of the autotransformer starter is that the action of the transformer, rather than the resistance, reduces the voltage; therefore, no energy is lost through heat. A disadvantage of this type starter is a temporary, but complete loss of power on the motor terminal when the motor is disconnected from the tranformer taps and transferred to the power line.

Figure 4-13A is a simplified schematic of an autotransformer having three laminated iron cores (one for each phase, star connected) wound with a coil of wire containing several taps to obtain a variation of voltages. The schematic (fig. 4-13A) indicates that each coil is connected at the center and connected to the 3-phase motor. This gives the motor only one-half of the line voltage at the start.

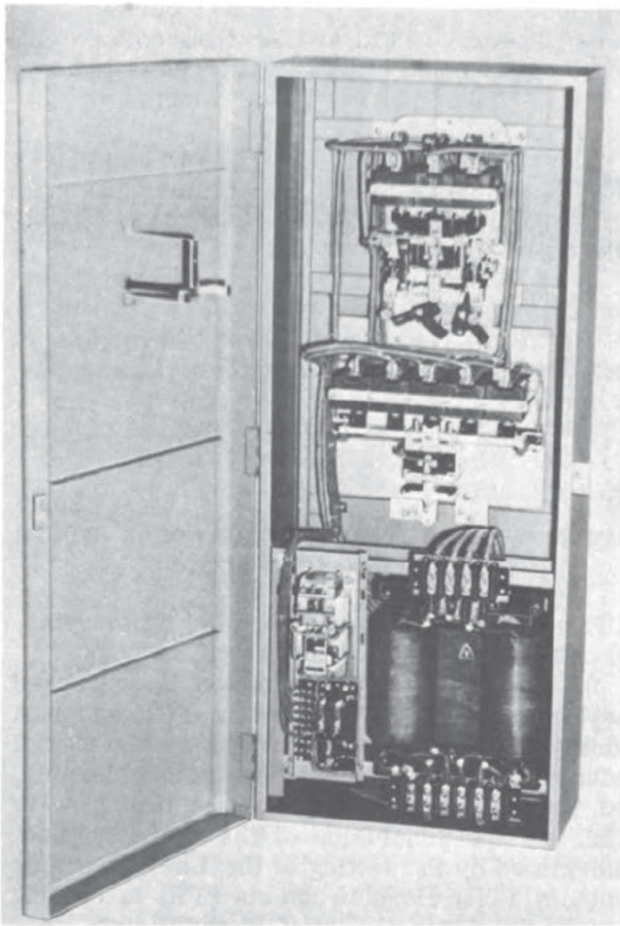
The control equipment in the schematic shown in figure 4-13B includes the START and RUN contactors, autotransformer, timer relay, control relay and overload relays.

In operation the start button if depressed energizes the START contactor (SC), which in closing connects the motor to the line by way of reduced voltage taps on the autotransformer, and simultaneously energizes the timing relay (TR). At the conclusion of the timing period, determined by the setting of the timer, the timer contacts (TR) close. Contacts (TR) in closing actuate the control relay (CR) which then functions to open the START contactor (SC) and energize the RUN contactor (RC). When the RUN contactor (RC) closes, the motor is connected directly across the line. Magnetic contactors (SC and RC) are cross-interlocked to prevent both units from closing. Simultaneous closing of these magnetic contactors would cause an overvoltage on the autotransformer.

Full line voltage is applied to the autotransformer primary. Starting current supplied at reduced voltage is higher than line current during this period. The usual time limit for bringing a loaded motor to two-thirds or more of its full speed is between 20 and 30 seconds.

STAR DELTA STARTING

The star delta starting method of reduced voltage can only be applied to motors having a delta connected winding that changes the motor terminal connection during the starting period. If the winding is changed from a delta connection to a star connection, the voltage across the windings is reduced to 57.7 percent



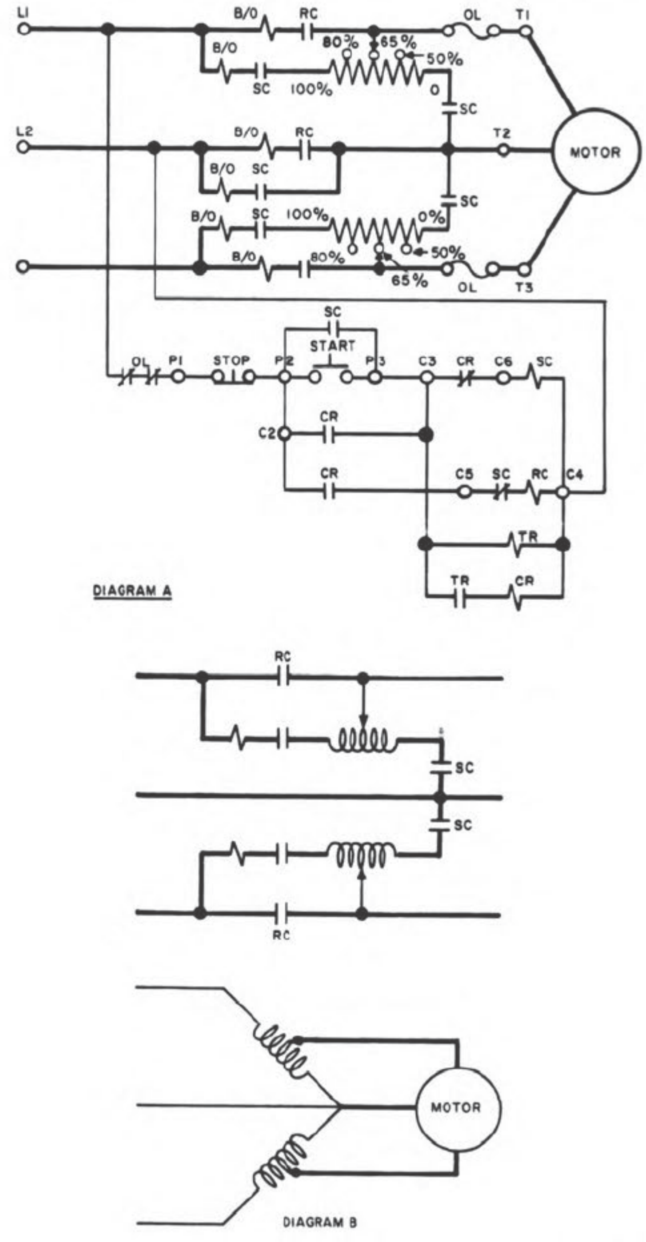
26.18X
Figure 4-12.—Autotransformer starter.

of the line voltage. After the motor is started, the windings are reconnected delta, and the voltage across them is line voltage.

All the phase leads are brought out to the terminal box, so that the connection may be easily changed.

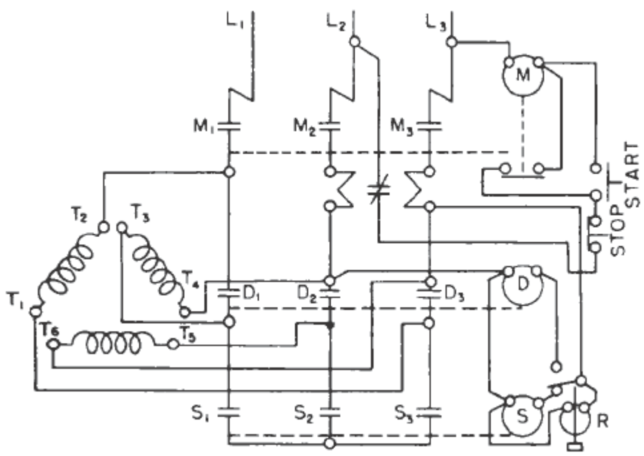
Figure 4-14 is a wiring diagram of a magnetic controller used for star delta starting. When the start button is depressed, contactor coil M is energized and closes contacts M1, M2, and M3, which connect phase leads T2, T4, and T6 across the line. At the same time, relay R and magnetic contactor S are energized. Contactor S closes S1, S2, and S3, which connect phase leads T1, T3, and T5 together. The motor winding is then star connected and connected across the line.

Relay R is a time relay. After a predetermined time delay, it opens the control circuit of



26.19X
Figure 4-13.—Line diagram of an autotransformer starter. B. Simplified schematics of the primary circuit.

contactors S and closes the control circuit of contactor D. Contactor S opens contacts S1, S2, and S3. Contactor D closes contacts D1, D2, and D3. Contacts D1, D2, and D3 connect T1, T3, and T5 to T6, T2 and T4 respectively and make a delta connection of the stator winding. Contacts M1, M2, and M3 remain closed so that the motor is connected across the line.



26.20
Figure 4-14.—Wiring diagram for a star-delta magnetic controller.

Thermal cutouts and relays, and other devices for motor-running protection which are not capable of opening short circuits, must be protected by fuses or circuit breakers. The rating or setting of these protective devices must not be over four times the rating of the motor for which they are designed. The only exception is when they are approved for group installation, and are marked to indicate the maximum size of fuse by which they must be protected.

A motor-running protective device which can restart a motor automatically after overcurrent tripping must not be installed unless approved for use with the motor which it protects. A motor which can restart automatically after shut-down must not be installed so that its automatic restarting can result in injury to personnel.

Motor-running overcurrent devices other than fuses must have a rating of not less than 115 percent, nor more than 125 percent of the full-load current rating of the motor.

SAFETY CODE FOR MOTORS AND MOTOR PROTECTION

In installing motors or motor controllers various requirements are necessary for safety of personnel and equipment. Below are some of the requirements for motor markings:

A motor shall be provided with a nameplate showing the maker's name, the rating in volts and amperes, including those of the secondary if a wound rotor type of motor, the normal full-load speed and the interval during which it can operate at full load starting cold, before reaching its rated temperature. The time interval shall be 5, 15, 30, or 60 minutes, or continuous.

A motor rated at 1/8 horsepower or larger shall have the horsepower rating marked on the nameplate except that the motors of arc welders may be marked in amperes.

An alternating current motor rated at 1/2 horsepower or larger, unless it is a polyphase wound-rotor motor, shall have the nameplate marked with a code letter to show its input in kilovolt-amperes with locked rotor.

SOME REQUIREMENTS FOR MOTOR CONTROLS AND MOUNTINGS

Controllers must show the manufacturer's name or symbol (for instance, SQUARE D); the voltage rating or ratings; the horsepower capacity or current carrying capacity; any data needed to indicate for what type of motor the controller is suitable; and terminal numbering (example, L1, L2, T1, and so on).

Control cabinets may not be used as a junction box, raceway, etc., for circuits containing apparatus other than the motor and controller connections.

Motors must be located so that: adequate ventilation is provided; maintenance such as lubrication of bearings and replacing of brushes can be readily accomplished; sparks from the commutator or collector rings will not cause fire hazards; and they are within sight of and not more than 50 feet from the controller.

The frames of stationary motors must be grounded. All motors must also be permanently and effectively grounded.

The preceding are but a few of the requirements for the installation of motors and their controls. If there is any doubt in your mind about the requirements for the installation of motors and their controls, or for almost any electrical requirements, you should consult the appropriate Navy or National electrical code or the appropriate Navy publication.

MAINTENANCE OF CONTROLLERS

The most important rule to remember when making repairs or inspecting motor controllers is — BE SURE THE CONTROLLER IS DISCONNECTED FROM THE POWER SOURCE BEFORE TOUCHING ANY OF THE OPERATING PARTS.

After the power source is disconnected, you can go ahead with your work. The first thing that should be done to keep controllers operating at maximum efficiency is to keep them free from dirt, dust, grease, and oil, both inside and out. Clean the operating mechanism and contacts with a clean, dry, lintless cloth, or with a vacuum cleaner. Small and delicate mechanical parts may be cleaned with a small, stiff bristle brush and a Navy approved solvent. NEVER USE CARBON TETRACHLORIDE.

If the manufacturer's instruction sheets for a device indicate bearing surfaces are to be lubricated, the bearing surfaces should receive a few drops of light oil, and all excess oil should be wiped off. In general, bearings which operate on a shaft or pin require lubrication. But knife edge bearings and plunger type armatures, which may become gummed up, SHOULD NOT BE OILED.

COPPER CONTACTS

Copper contacts are used for most heavy duty power circuits, and in many cases, in relay and interlock circuits. They should be inspected regularly. If projections extend beyond the contact surfaces, or if the contacts are pitted or coated with copper oxide, they should be dressed down with fine sandpaper.

Welding of contacts sometimes occurs. In spite of all precautions, low voltage is the most common cause. Welding may also result from overloads, low contact pressure resulting from wear or weak springs, loose connections, or excessive vibrations. If welding occurs, it is an indication of trouble in the electrical system. The contacts will have to be replaced, but it is useless to replace them unless the cause of the welding is found and corrected.

CARBON CONTACTS

Carbon contacts are used when a contactor is frequently opened and closed. It is essential that the contactor be open when it is deenergized. Since carbon contacts will not weld together when closed, they are better than metal contacts for ensuring that a deenergized contact is open. Carbon contacts are used only when necessary, however, because the current capacity of carbon per square inch of contact surface is very low; therefore the contacts made of carbon must be relatively large.

SILVER CONTACTS

Silver contacts are used extensively in pilot and control circuits, on relays, interlocks, master switches, and so on. They are used also on smaller controllers, and on heavy duty equipment where the contactors remain closed for long periods of time with infrequent operation. Silver contacts are used because they ensure better contact than other less expensive material.

Pure silver contacts and silver cadmium-oxide contacts should not be placed until they become too worn to give good service. Their appearance will indicate when they are worn to such an extent that they are not longer serviceable. (See fig. 4-15.)

Normally, contacts are subjected to electrical and mechanical wear as they establish and interrupt electric currents. Electrical wear is usually greater than mechanical wear. If a movable contact assembly has no appreciable sliding action on its associated stationary contact assemblies, mechanical wear will be insignificant.

Electrical wear or erosion is caused by arcing when the contacts are establishing and interrupting currents. During arcing, a small part of each contact is melted, vaporized, and blown away from the contact.

As a pure silver contact erodes, its arcing surface changes in color, contour, and smoothness. Figure 4-15 shows typical changes in contour and smoothness.

Normally, a new contact has a uniform silver color, a regular contour, and a smooth arcing surface. As the contact wears, discolorations usually give it a mottled appearance, showing silver, blue, brown and black. The black color comes from the silver oxide formed during arcing. Silver oxide is beneficial to the operation of the contact.

Electrical erosion may cause uneven wear of the contacts and consequent contour-irregularity. Uneven contact wear does not necessarily indicate that the contact be replaced. To allow for uneven contact wear, manufacturers usually provide a total thickness of silver equal to twice the wear-allowance associated with the contact.

Melting and vaporization of contacts cause pitting of the arcing surface. The pitted surface has high spots which are quite small in area; tests indicate that such a surface is better than a surface which has not been subjected to arcing, because its circuit-making reliability is improved.

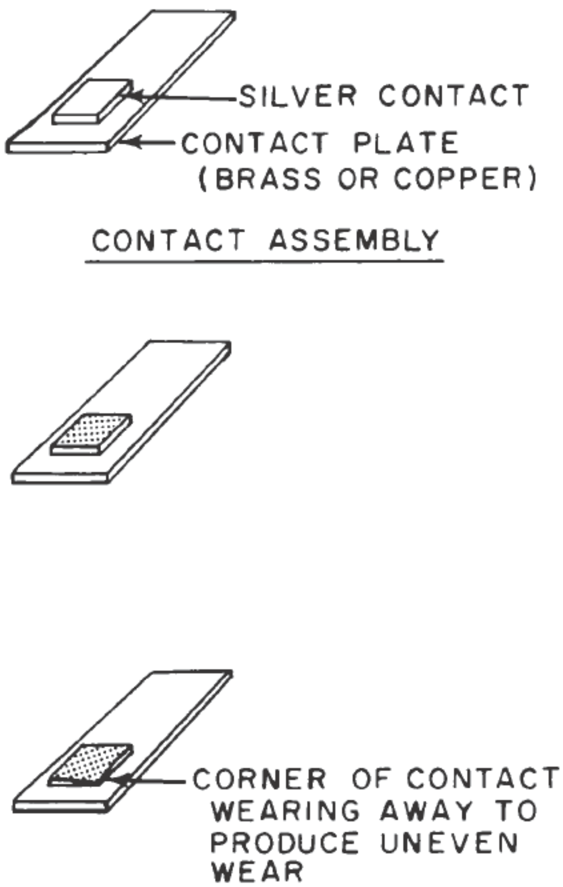


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Figure 4-15.—Silver contact.

A silver-cadmium-oxide contact shows the same wear characteristics as a pure silver contact, except that small black granules may be evident on the arcing surface. These granules are cadmium oxide, a black material which is scattered throughout the mixture which has formed on the contacts. Silver oxide is formed during arcing, just as with a pure silver contact. The addition of cadmium oxide greatly improves contact operation because it minimizes the tendency of the contacts to weld together, retards heavy transfer of material from one contact to the other, and inhibits erosion.

A contact is servicable as long as its wear-allowance and that of its associated contacts exceed minimum value specified by the manufacturer. (Usually the minimum value is in the order of 0.015 to 0.030 inch.) The wear-allowance of contacts is defined as the total thickness of contact material which may be worn away before the contact of two associated surfaces becomes inadequate to carry rated current.

In an electric-motor contactor, the wear-allowance of the power pole contacts is usually related to the closed position of the magnetic operator. The wear-allowance of the power-pole contacts of a magnetic contactor is the amount of silver that can be worn away without resulting in a failure of contacts to touch when the magnetic operator is at its closed position.

BLOWOUT COILS

Blowout coils seldom wear out or give trouble when used within their rating. However, if they are required to carry excessive currents, the insulation becomes charred and fails, causing flash-overs and failure of the device.

Arc shields are constantly subjected to the intense heat of arcing and may eventually burn away, allowing the arc to short circuit to the metal blowout pole pieces. Therefore, arc shields should be inspected regularly and renewed before they burn through.

Arc barriers provide insulation between electrical circuits and must be replaced if broken or burned to a degree where short circuits are likely to occur.

The importance of having clean, tight electrical connections cannot be overemphasized. Where practical, it is a good idea and a common practice to solder electrical connections.

Excessive slam on closing, particularly on a-c magnet-operated devices, will eventually damage the laminated face of the magnet armature and may damage the shading coil.

Magnet coils should be kept dry. Wet coils should always be dried out before using. They may be dried by baking them in an over at 230° to 257° Fahrenheit. The length of time in the oven depends on the size of the coil.

Table 4-2 is a troubleshooting chart for a-c controllers.

VOLTAGE REGULATORS

Uniform voltage on feeder circuits is maintained by automatically operated voltage regulators that raise or lower the circuit voltage as load demands change. The voltage regulators discussed in this chapter are the single-phase station type induction and step voltage regulators that are used on primary distribution feeders. Although the details of construction of these regulators are different, their operating and control devices are similar.

Table 4-2. —Troubleshooting Chart for A-C Controllers.

Trouble	Probable cause	Remedy
Failure to close	No power.	Check power source. Replace faulty fuses.
	Low voltage.	Check power-supply voltage. Apply correct voltage. Check for low power factor.
	Inadequate lead wires.	Install lead wires of proper size.
	Loose connections.	Tighten all connections.
	Open connections and broken wiring.	Locate opens and repair or replace wiring. Remove dirt from controller contacts.
	Contacts affected by long idleness or high operating temperature.	Clean and adjust.
	Contacts affected by chemical fumes or salty atmosphere.	Replace with oil-immersed contacts.
	Inadequate contact pressure.	Replace contacts and adjust spring tension.
	Open circuit breaker.	Check circuit wiring for possible fault.
	Defective coil.	Replace with new coil.
	Overload-relay contact latched open.	Operate hand- or electric-reset.
Failure to open	Interlock does not open circuit.	Check control-circuit wiring for possible fault. Test and repair.
	Holding circuit grounded.	Test and repair or replaced grounded parts.
	Misalignment of parts; contacts apparently held together by residual magnetism.	Realign and test for free movement by hand. Magnetic sticking rarely occurs unless caused by excessive mechanical friction or misalignment of moving parts. Wipe off pole faces to remove accumulation of oil.
	Contacts welded together.	See CONTACTS WELDED TOGETHER section.
Sluggish Operation	Spring tension too strong.	Adjust for proper spring tension.
	Low voltage.	Check power-supply voltage. Apply correct voltage.
	Operating in wrong position.	Remount in correct operating position.
	Excessive friction.	Realign and test for free movement. by hand. Clean pivots.
	Rusty parts due to long periods of idleness.	Clean or renew rusty parts.
	Sticky moving parts.	Wipe off all accumulations of oil and dirt. Bearings do not need lubrication.
	Misalignment of parts.	Check for proper alignment. Realign to reduce friction and test for free movement by hand.

Table 4-2. —Troubleshooting Chart for A-C Controllers—Continued

Trouble	Probable cause	Remedy
Erratic Operation (Unwanted Openings and Closures and Failure of Overload Protection)	Short circuits.	Test and repair or replace defective parts.
	Grounds.	Test and repair or replace defective parts.
	Sneak currents.	These are usually caused by intermittent grounds or short circuits in the machines or wiring circuit. Test and replace faulty parts or wiring.
	Loose connections.	Tighten all connections. Eliminate any vibrations or rapid temperature changes that may occur in close proximity to the controller.
Overheating of Coils	Shorted coil.	Replace coil.
	High ambient temperature or poor ventilation.	Relocate controller, use forced ventilation or replace with suitable type controller.
	High voltage.	Check for shorted control resistor. Check power-supply voltage. Apply correct voltage.
	High current.	Check current rating of controller. Make check for high voltage above. If necessary, replace with suitable type controller.
	Loose connections.	Tighten all connections. Check for undue vibrations in vicinity. .
	Excessive collection of dirt and grime.	Clean but do not reoil parts. If covers do not fit tightly, realign and adjust fasteners.
	High humidity, extremely dirty atmosphere, excessive condensation, and rapid temperature changes.	Use oil-immersed controller or dusttight enclosures.
	Operating on wrong frequency.	Replace with coil of proper frequency rating.
	D-C instead of a-c coil.	Replace with a-c coil.
	Too frequent operation.	Adjust to apply larger control.
	Open armature gap.	Adjust spring tension. Eliminate excessive friction or remove any blocking in gap.
Contacts Welded Together	Improper application.	Check load conditions and replace with a more suitable type controller.
	Excessive temperature.	Smooth off contact surface to remove concentrated hot spots.
	Excessive binding of contact tip upon closing.	Adjust spring pressure.

Table 4-2. —Troubleshooting Chart for A-C Controllers—Continued.

Trouble	Probable cause	Remedy
Contacts Welded Together (Continued)	Contacts close without enough spring pressure.	Replace worn contacts. Adjust or replace weak springs. Check armature overtravel.
	Sluggish operation.	See SLUGGISH OPERATION.
	Rapid, momentary, touching of contacts without enough pressure.	Smooth contacts. Adjust weak springs. Where controller has "JOG" or "INCH" control button, operate this less rapidly.
Overheating of Contacts	Inadequate spring pressure.	Replace worn contacts. Adjust or replace weak springs.
	Contacts overloaded.	Check load data with controller rating. Replace with correct size contactor.
	Dirty contacts.	Clean and smooth contacts.
	High humidity, extremely dirty atmosphere, excessive condensation, and rapid temperature changes.	See OVERHEATING OF COILS.
	High ambient temperature or poor ventilation.	See OVERHEATING OF COILS.
	Chronic arcing.	Adjust or replace arc chutes. If arcing persists, replace with a more suitable controller.
	Rough contact surfaces.	Clean and smooth contacts. Check alignment.
	Continuous vibration when contacts are closed.	Change or improve mounting of controller.
	Oxidation of contacts.	Keep clean, reduce excessive temperature, or use oil-immersed contacts.
Arcing At Contacts	Arc not confined to proper path.	Adjust or renew arc chutes. If arcing persists, replace with more suitable controller.
	Inadequate spring pressure.	Replace worn contacts. Adjust or replace weak springs.
	Slow in opening.	Remove excessive friction. Adjust spring tension. Renew weak springs. See SLUGGISH OPERATION.
	Faulty blowout coil or connection.	Check and replace coil. Tighten connection.
	Excessive inductance in load circuit.	Adjust load or replace with more suitable controller.
Pitting or Corroding of Contacts	Too little surface contact.	Clean contacts and adjust springs.
	Service too severe.	Check load conditions and replace with more suitable controller.
	Corrosive atmosphere.	Use airtight enclosure. In extreme cases, use oil-immersed contacts.

Table 4-2. —Troubleshooting Chart for A-C Controllers—Continued

Trouble	Probable cause	Remedy
Pitting or Corroding of Contacts (Continued)	Continuous vibration when contacts are closed.	Change or improve mounting of controller.
	Oxidation of contacts.	Keep clean, reduce excessive temperature, or use oil-immersed contacts.
Noisy Operation (Hum or Chatter)	Poor fit at pole face.	Realign and adjust pole faces.
	Broken or defective shading coil.	Replace coil.
	Loose coil.	Check coil. If correct size, shim coil until tight.
	Worn parts.	Replace with new parts.
Vibration after Repairs	Misalignment of parts.	Realign parts and test for free movement by hand.
	Loose mounting.	Tighten mounting bolts.
	Incorrect coil.	Replace with proper coil.
	Too much play in moving parts.	Shim parts for proper tightness, and clearance.

INDUCTION REGULATOR

The induction voltage regulator consists of a fixed (secondary) and movable (primary) winding which rotates through 180° only. A motor and brake with a contact making voltmeter, line-drop compensator, and controls provide either automatic or manual operation. The regulator is normally designed for plus or minus 10 percent variation of the primary distribution voltage. The secondary winding is arranged in two coils which may be connected in series or in parallel, making possible the reconnection of a 10 percent regulator to provide only 5 percent regulation having double the current capacity. Figure 4-16 shows a cross section of an induction regulator. Figures 4-17 and 4-18 are line diagrams of an induction regulator compensator.

Figure 4-18 is a simplified schematic diagram of an automatically controlled induction regulator. Normally, the operation is as follows: When the voltage of the feeder is normal, the plunger of the voltage relay is in the middle position; the motor line switch is open; and the induction regulator is neither bucking nor boosting the voltage. When the feeder voltage drops, the plunger in the relay drops. This closes the switch in the motor circuit and causes the motor to rotate in the direction which will boost the voltage. The motor rotates until the voltage is raised to a point which will lift the relay plunger to its medium position. Should the voltage be increased above normal, the relay plunger would go above the medium position, thereby closing a contact above. Closing this contact forces the motor switch to close in the opposite direction, thereby reversing the rotation of the motor. This will now cause the regulator to buck the voltage and lower it back to normal value. In all cases, the shunt winding is rotated until the voltage is brought to its normal value.

STEP VOLTAGE REGULATOR

The step voltage regulator provides economical and reliable regulation. This type consists essentially of a core and coil assembly, switching mechanism, motor, and control for both manual and automatic operation. Ordinarily all moving parts are accessible for inspection; this aids materially in reducing maintenance cost. Procedures for adjustments and normal

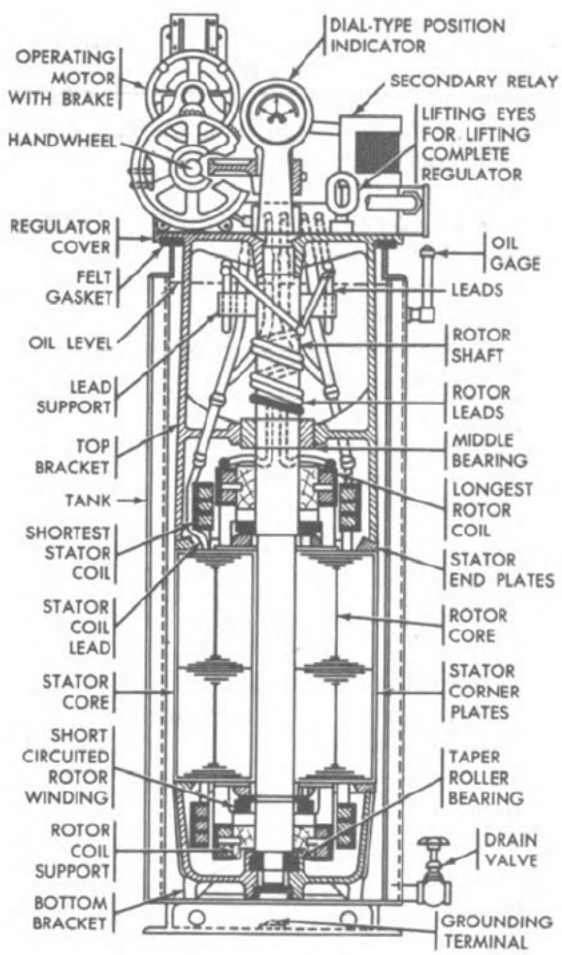

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Figure 4-16.—Cross section of an induction regulator.

maintenance usually are covered adequately in the manufacturer's instruction book provided with the equipment. Figure 4-19 shows a cutaway view of a step voltage regulator.

Figure 4-20 is a simplified wiring diagram of an automatically controlled step voltage regulator. The diagram is a 3-phase composite transformer with delta connected primaries and Y connected secondaries. Inserted in each phase wire is a series boosting transformer, the primaries of which are supplied through preventive coils and the tapped Y connected secondaries. The "tap changers" are motor driven and are immersed in oil.

In actual application you can use two single-phase regulators to regulate a 3-phase, 3-wire circuit adequately. Three single-phase regulators are required for a 3-phase, 4-wire circuit.

Operation

Preliminary regulator adjustments for automatic operation are usually made from voltmeter readings at the load center during peak and off peak periods. A field man communicates the reading to the station operator who adjusts the regulator to deliver the desired voltage.

To maintain a reasonably constant voltage on the circuit, a measurement of the voltage at the load center must be obtained. If the regulators to be tested are in service and the contact making voltmeter and taps on the line-drop compensator (shown on fig. 4-18, but not on fig. 4-19) have been temporarily adjusted, the following procedure applies:

1. Choose a location at or near the load center of the circuit for obtaining voltage measurement records.

2. If lightly loaded transformers are available, they can generally be used with satisfactory results. If not, suitable potential transformers are connected across the phases to be tested. On 3-phase circuits, two of the phases should be tested simultaneously.

3. Install recording voltmeters at the secondary terminals of the transformers. These voltmeters should be tested and adjusted for accuracy before installation.

4. Leave the voltmeter in service for at least 24 hours. Remove the charts and reset the chart to be left on the voltmeters for further tests if required.

5. Study removed charts. If voltage is correct throughout the test period, make no further regulator adjustments. If voltage is uniformly too low or too high throughout the period, assume the line-drop compensator adjustment to be correct, but make further adjustments of contact making voltmeters. If voltage is too high or too low during heavy or peak load periods, but is correct during normal or light periods, assume the contact-making voltmeters adjustment to be correct, but make further adjustments of the line-drop compensator. For overvoltage, change taps to decrease compensation; for undervoltage, change taps to increase compensation. Frequently, voltage conditions required further adjustment on both contact making voltmeters and line-drop compensators. Most line-drop compensators have 24 1-volt steps across the resistance portion, and 24

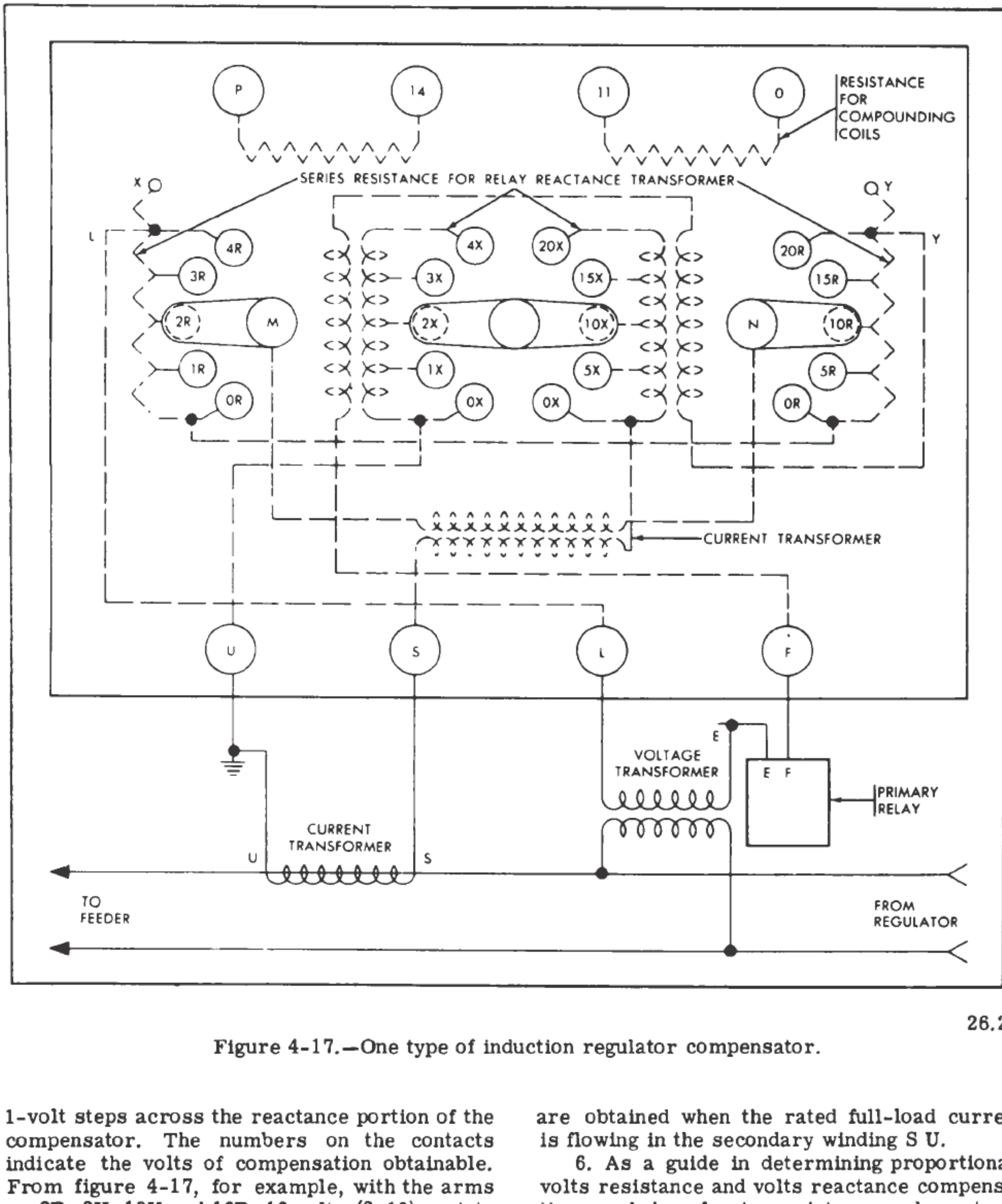

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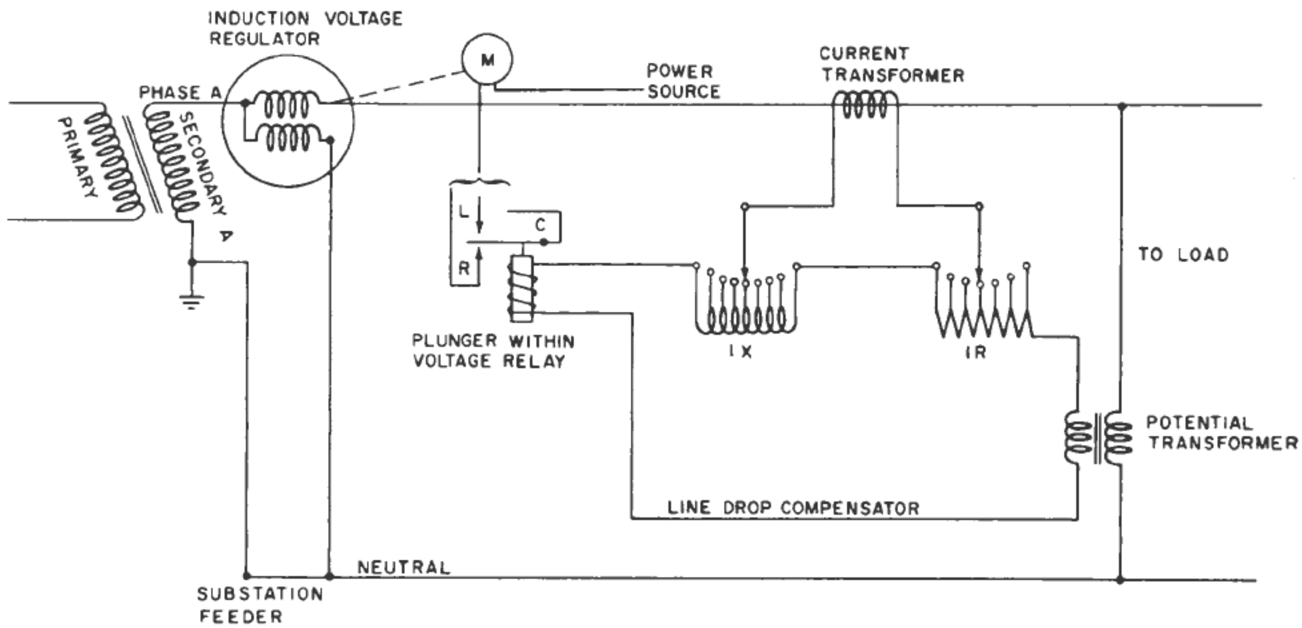
Figure 4-17.—One type of induction regulator compensator.

1-volt steps across the reactance portion of the compensator. The numbers on the contacts indicate the volts of compensation obtainable. From figure 4-17, for example, with the arms on 2R, 2X, 10X and 10R, 12 volts (2+10) resistance and 12 volts (12+10) reactance compensation are obtained when the rated full-load current is flowing in the secondary winding S U.

6. As a guide in determining proportionate volts resistance and volts reactance compensation needed, refer to resistance and reactance tables found in most electrical engineering



26.24

Figure 4-18.—Schematic wiring diagram of an automatically controlled induction regulator.

handbooks. For example, on a 1/0 copper conductor circuit having an equivalent distance of 18 inches between conductors, a selected table from an electrical engineering handbook shows resistance in ohms per 1,000 ft to be 0.1002, and the reactance to the neutral in ohms per 1,000 ft of one conductor of single or 3-phase circuit to be 0.1126 (ratio of 0.1002R to 0.1126X). Therefore, the circuit as indicated would need slightly more reactance compensation than resistance compensation. NOTE: For single-phase regulators on 3-phase circuits, adjustments may vary for each regulator because of unbalanced load conditions, variations in conductor spacing, and other variables.

7. After the charts have been studied and initial adjustments have been completed, leave the voltmeters in service for another 24-hour period. Study the charts for this second period and make further adjustments of regulator devices if necessary.

8. Continue the procedure as outlined until a reasonably constant voltage at the load center is maintained. One or two adjustments usually give satisfactory results. Ordinarily, a range within plus and minus 10 percent is acceptable.

9. For removing or replacing regulators and connections for single-phase regulators in various combinations and circuits, refer to applicable manufacturers' drawings.

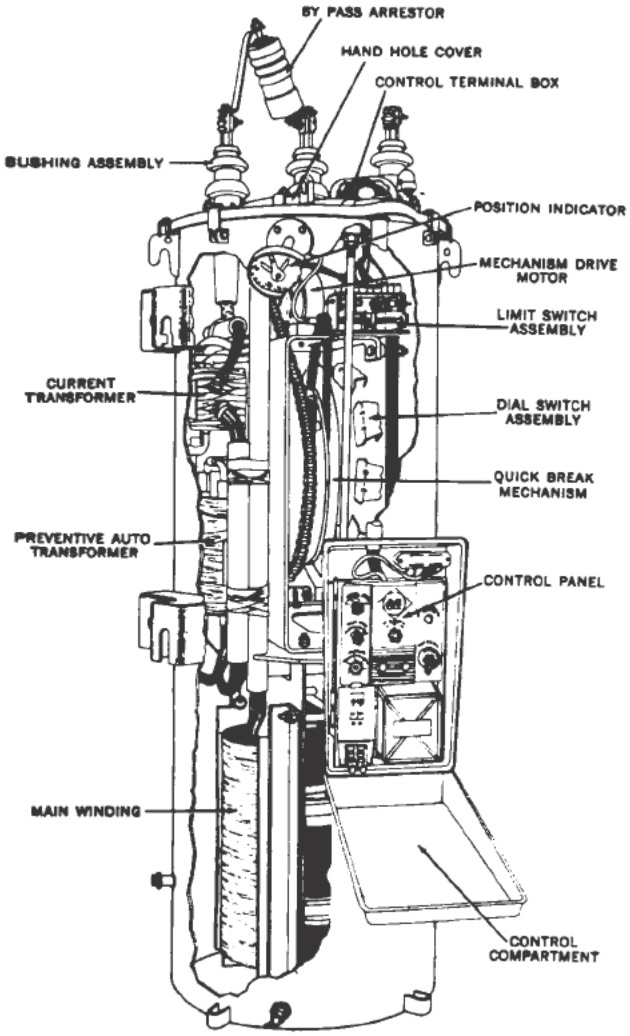
Putting Regulator Into Service

Most regulator installations are provided with isolating and bypassing disconnecting switches. The following procedure should be followed to place a regulator into service:

1. Check the nameplate data against the requirements of voltage and current. If the secondary has double current rating, connect the coils in series or multiple according to the capacity required. Tag the line and load sides of the regulator and operating motor for correct phase rotation.

2. To deenergize the feeder, open the circuit breaker at the switchboard controlling the feeder and regulator. Open the regulator isolating disconnects. If service must be maintained, close the bypassing disconnect and then close the circuit breaker at the switchboard. Position the regulator properly to accommodate incoming and outgoing connections without crossovers, and make the grounding connection first.

3. Make certain that the case is grounded through a heavy copper connection to the ground



26.25

Figure 4-19.—Cutaway view of a step voltage regulator.

bus. The surface at the gounding point on the regulator should be clean, and a positive connection should be made.

4. For connections at regulators, refer to the diagram furnished with the apparatus. The corresponding primary and secondary coils must be connected to the same phase wires in the proper direction; otherwise, maximum regulation will not be secured, or the regulator will not function properly. Incorrect current direction will increase losses and heating. When the regulator under load is turned from either full buck or boost to neutral, the primary current should decrease. If it increases, reverse the line and load conductors of the regulator.

5. After the regulator is installed, make a thorough check of the connections. Then the isolating disconnects may be closed and the bypassing disconnect opened.

Cutting Regulator Out of Service

The following is recommended procedure for cutting regulator out of service:

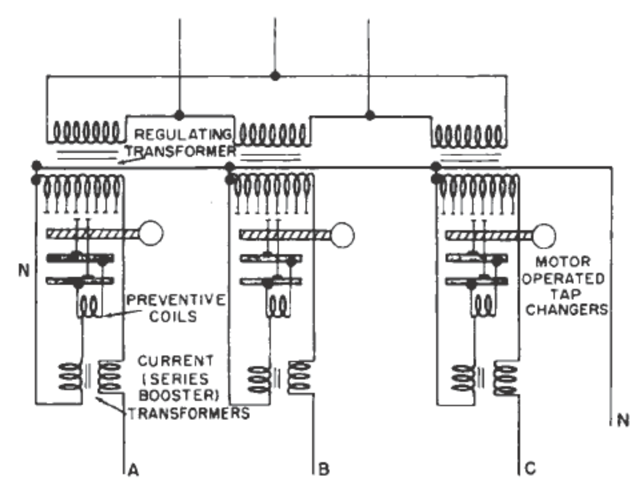
1. Deenergize the feeder as described in the previous section, and isolate the regulator completely. If service on the feeder must be continued, close the bypassing disconnecting switch and close the feeder circuit breaker at the switchboard.

2. To disconnect the regulator, cut or open all circuit leads to the regulator, tagging them according to line and load sides. If necessary, trace the conductors back to the bus or other point, making positive identification.

Maintenance

Instructions contained in this paragraph apply in general to induction regulators. Complete maintenance procedures are covered in manufacturers' publications and should be followed in each instance.

When work is done near a regulator on a live circuit, extreme care shall be used in guarding against certain hazards. Frequently,



26.26

Figure 4-20.—Schematic view of a step voltage regulator.

cables from the regulators are unprotected except for the cable insulation, which may be insufficient to protect a person in direct contact with it. If lubrication is necessary, the automatic control should be opened and tagged to prevent operation.

Newer regulators have accessible oil cups and standard fittings to facilitate lubrication. Some outdoor regulators have a lamp placed in the top covering near the operating motor. This lamp is kept lighted during cold weather to prevent the oil in the motor bearings from congealing. In more modern equipment, strip heaters are installed to accomplish the same purpose and to maintain a dry atmosphere within the enclosure. Although the transformer oil in a regulator ordinarily does not need much attention, occasional inspection must be made for signs of leaks about the casing. The oil level should be checked regularly, either through a gage glass or through a hole in the enclosures. The oil must never be allowed to get below the bottom of the gage glass or below the tops of the winding. The following schedule for oiling is suggested:

1. Lubricate the top bearings every month by oiling the felt ring around the shaft in the recess at the top.
2. Lubricate the gear segment and worm with heavy grease every 6 months.
3. Keep the oilcups on motor bearings and worm-shaft bearings filled. A good grade of ballbearing grease should be used for motors having greased ball bearings.
4. Keep the grease cups filled on the rotary magnetic brake release (if used).
5. Place a drop of oil occasionally on the wearing points of other types of electrical brake-release mechanisms.
6. Be sure that the correct amount of oil is used. Any excess may be thrown on the brakeshoe, reducing brake effectiveness and causing the regulator to overrun.

Troubleshooting

The following points require attention, either at times of regular inspection or when locating causes of trouble:

If the regulator stalls or is sluggish in its operation, make the following checks and adjust if necessary:

1. Worm or sector gears may have changed their positions on the shaft. Correct by readjustment of gears.
2. Either the top or bottom bearing of the rotor shaft may be too tight. Dismantle the regulator for inspection and correction of the trouble.
3. Foreign matter may have become jammed in the gears.
4. The brake release may be inoperative, allowing the brake to drag continuously.

If a fuse is blown and a 220-volt supply switch is in the circuit, open it and replace the fuse; after that, close the switches again. If the wiring to any one motor is short circuited, open the automatic control switch for that motor circuit and leave it open when trouble is detected. The fuses may be blown by the combined starting currents of a number of motors at periods of rapid load changing or voltage disturbance on the bus.

Every 6 months the position indicator should be checked as follows:

1. Check all connections.
2. Check the indicator for accuracy if it is used for setting the regulator position when paralleling circuits.
3. Check signal lights (if provided) for maximum buck and maximum boost indication.
4. Check for automatic return to neutral position.

Heating may be detected by feeling the temperature of the drive motor casing, particularly during periods of rapid load changing. Failure of the circuit voltmeter to hold at the correct value may indicate a stalled motor. Humming of the motor without proper speed of rotation may be caused by single-phase condition. In the case of old regulators, check the limit switch to see if one contact opens before the other.

1. In some cases, the motor may move in jumps because of impulses of current when the relay switch makes contact; but it may move by jumps or inch along to the extreme position in the wrong direction, failing to clear on the limit switch.
2. If the motor overheats or acts sluggish, open the automatic control switch to prevent damage. Rotate the regulator by hand to detect mechanical trouble such as tight bearings, dry bearings, worn and sector gears binding, rotor binding or jammed against the limit stop, brake not releasing or too tight, or congealed oil in regulator motors outdoors. Low voltage or a single-phase condition of the supply circuit may cause sluggish action.

CAUTION: Before rotating the regulator by hand, open the automatic control switch to prevent personal injury that might result from the effort of the automatic controls to readjust voltage after changing voltage by hand operation. Any oiling or adjustment of the motor or gearing should be done only after automatic control has been removed.

CONSTANT-CURRENT REGULATOR

There are several lighting circuits that are basically alike and make use of the constant-current (C-C) regulator in controlling the circuits. The constant-current regulator is used in controlling the following types of circuits:

1. Street lighting
2. Area lighting
3. Airfield lighting

MOVING-COIL TYPE OF C-C REGULATOR

The constant-current regulator (see fig. 4-21) is a transformer with a movable secondary winding that positions itself to provide constant current for any load within its rating. The balance point between coil weight and magnetic force may be adjusted to provide the desired secondary current (usually 6.6 amperes).

CONTROLS AND PROTECTION

The controls and protection used in conjunction with the constant-current regulator are shown in figure 4-22. The lightning arresters, time switch, photoelectric cell, fused cutouts, oil switch, protective relay and manual switch are pieces of equipment used along with the C-C regulator for the three kinds of lighting circuits listed earlier.

PHOTOELECTRIC RELAYS

Photocell relays are used to turn on lighting circuits when natural illumination falls below a predetermined level and to turn them off when it rises to a slightly higher level. Two types of light sensitive cells are used: (1) a light collector (shown in fig. 4-23) which generates energy to operate the relay directly, and (2) a phototube, which requires the help of a vacuum tube to operate the relay.

Self-Generating Type of Photocell

The self-generating photronic cell has a normal clear-day output of 1 1/2 to 6 milliamperes. It will, however, operate the relay on 1/2 milliampere so that replacement of the light collector is not necessary until its output tests below 1/2 milliampere. Tests of current output are made most conveniently at the terminals on the relay box (fig. 4-24) and should be made on a cloudless day using a milliammeter having a range of 0 to 10 milliamperes. When the output of the light collector test less than 1/2 milliampere, it should be returned to the manufacturer for rehabilitation.

Nongenerating Phototube-type of Photocell

The phototube photoelectric relay should be checked every month. The windows should be cleaned and all tubes replaced. Replaced tubes should be checked by a competent tester and discarded if poor. Any extensive maintenance work should be done by the manufacturer.

AUTOMATIC BOILER CONTROLS

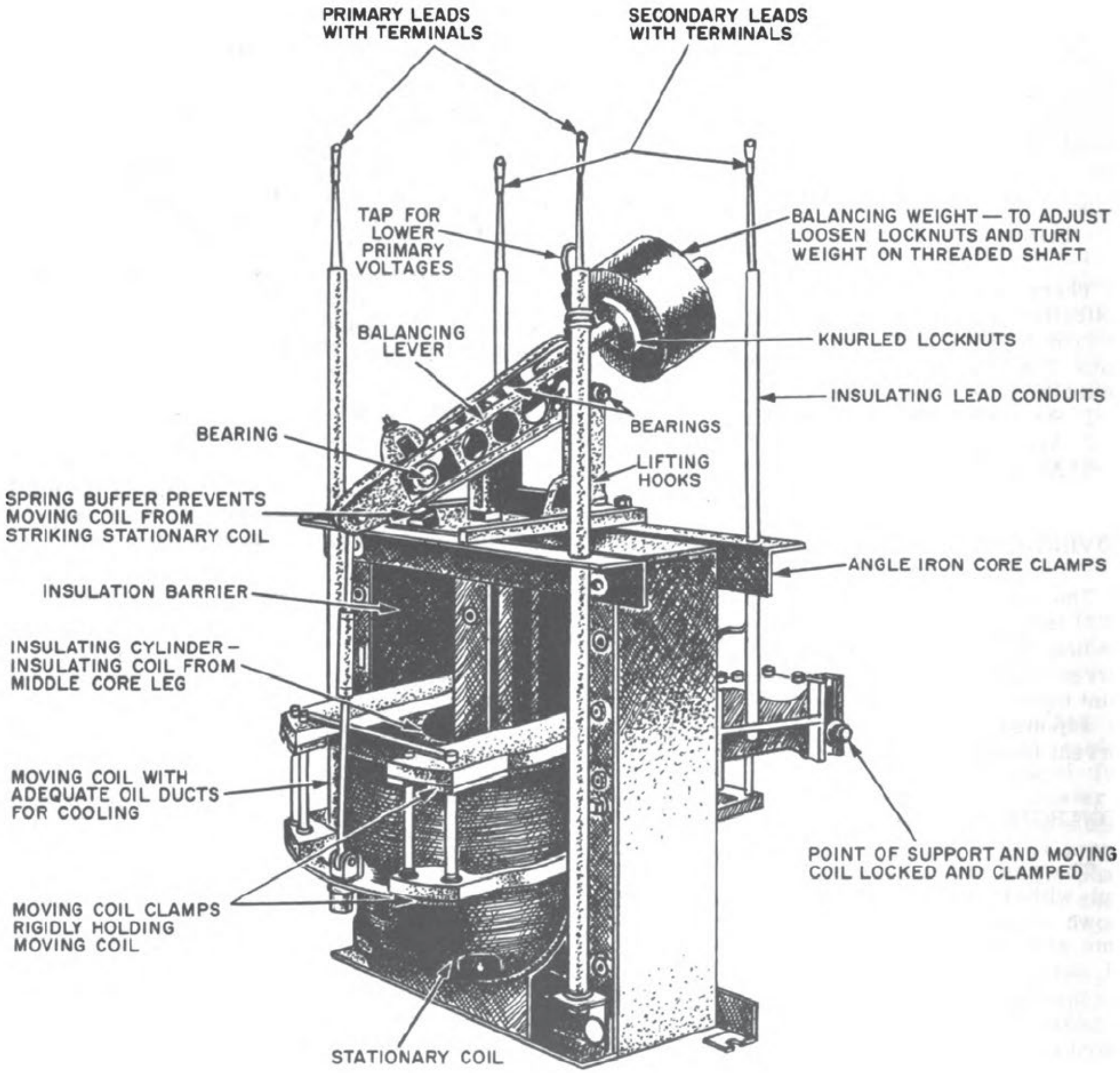
The term "controls," when applied to boiler plants, refers to devices which control the water level and flow, steam pressure and flow, temperature, draft, fuel feed, and combustion. Controls also provide safeguards in case of flame failure or water supply failure.

WATER LEVEL CONTROLS

An imbalance in the amount of fluid flowing into and out of steam generating equipment causes a change in the water level in the boiler, tank, or other vessel in the system. The change in level is detected by a level control or float control which actuates other devices that restore the balance and/or cut off the fuel supply if the water falls to a dangerous level. Two common types of water level controls are the electrode probe and the float.

Electrode probe

One type of water level control is the electrode probe which operates the boiler feed pump and also protects the boiler against low water by securing the source of heat. An electrode



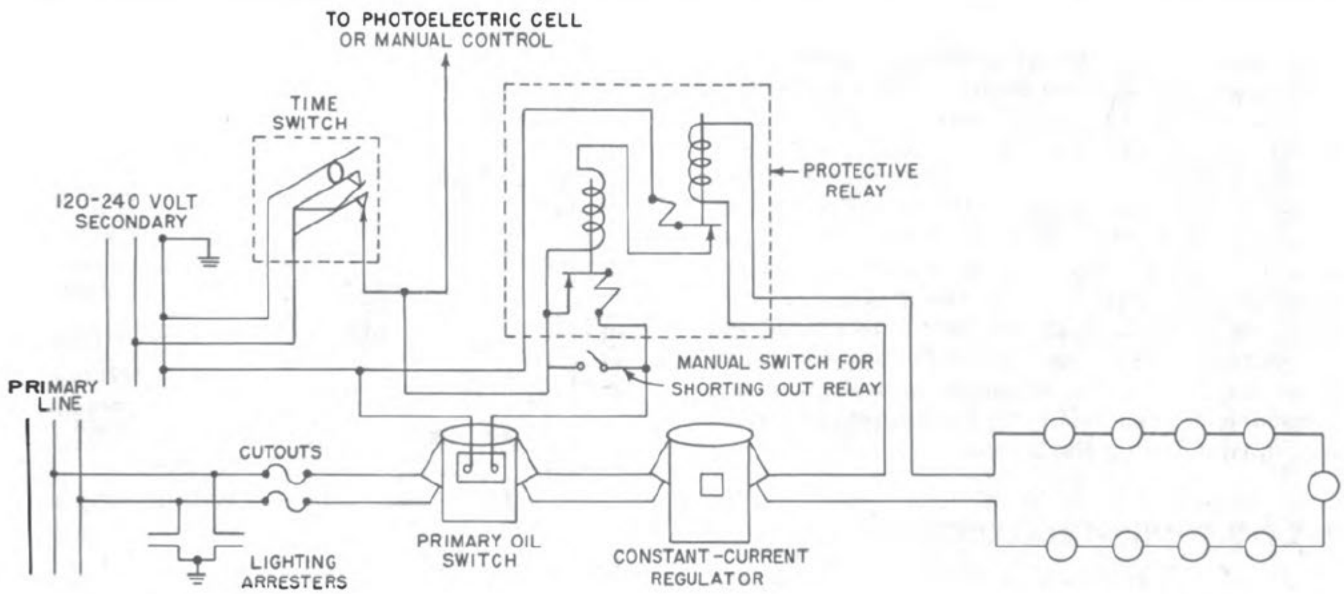
26.181

Figure 4-21.—Moving coil type of constant-current regulator.

assembly inserted at the top of the boiler has three electrodes of different lengths which extend down to the water level of the boiler (see fig. 4-25). A-C current is supplied to the electrodes from a transformer in the water level relay. Should the water level recede below the longest electrode, a low-water alarm horn sounds and the burner stops. The middle and shortest electrodes actuate the boiler feed pump; the shortest electrode stops the pump, and the middle electrode starts the pump.

Float

Another type of water level control is the simple float which rises and falls at the water surface. The float may be mounted in the boiler tank or in a separate float chamber. The float



26.182

Figure 4-22.—Controls and protection for series lighting circuit.

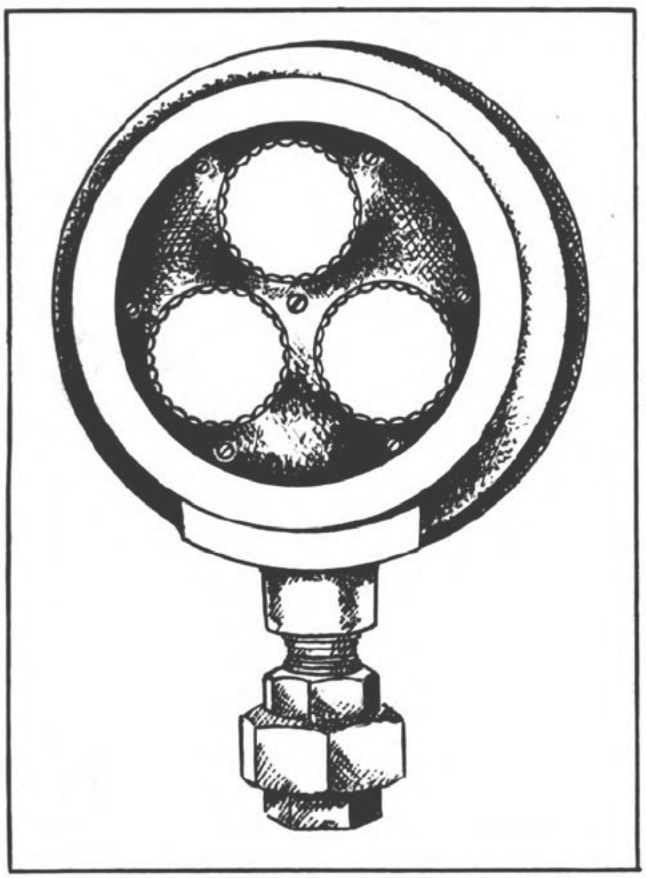


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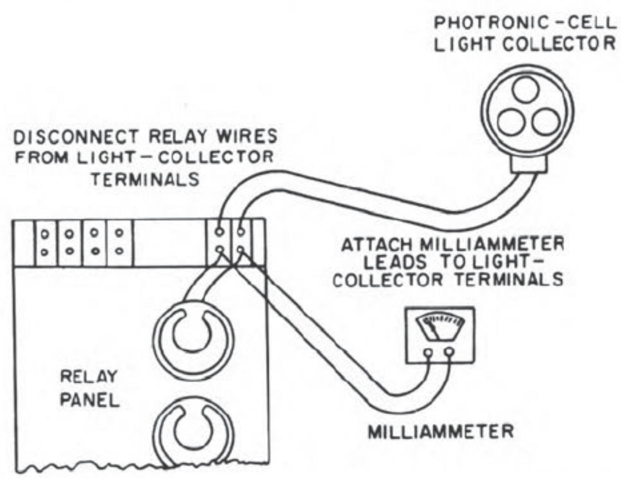
Figure 4-23.—Photoelectric cell (light collector).



26.184

Figure 4-24.—Method of checking output of photronic cell.

is sometimes connected directly to a water intake control valve. The float may, instead, operate a relay mechanism. A relay system has advantages over the float-valve connection in that the control device can be located at a considerable distance from the float and the water level can be controlled within closer limits.

PRESSURE LIMIT SWITCH

The boiler high-limit steam pressure is controlled by the pressure switch, sometimes

called "the Pressuretrol" after a common trade name. The Pressuretrol is a part of the control system for automatic operation of steam generators. It is used in series with the low water cut off and the burner control. A typical pressure switch is shown in figure 4-26. When there is sufficient water in the boiler, steam is generated and acts upon the bellows. The bellows in turn operate a mercury (single-throw) switch or single pole switch. When the steam pressure is below the high limit, the switch is closed and the current passes on to the burner control to start the fire cycle. When the high limit steam pressure is reached, the Pressuretrol switch will open and stop the burner.

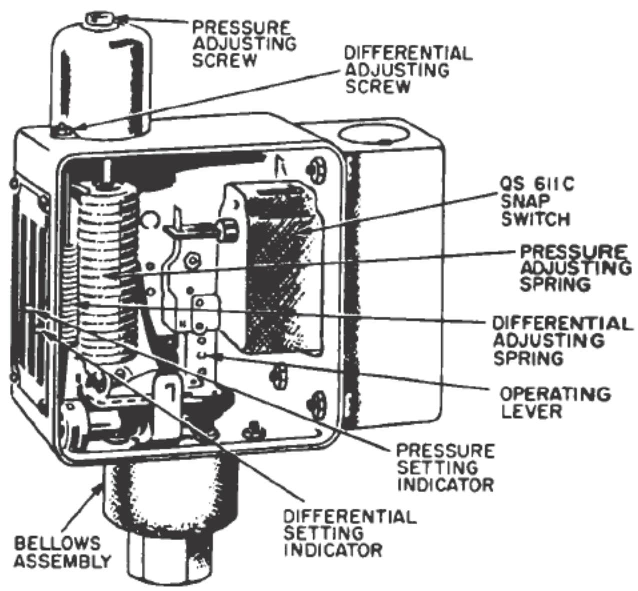


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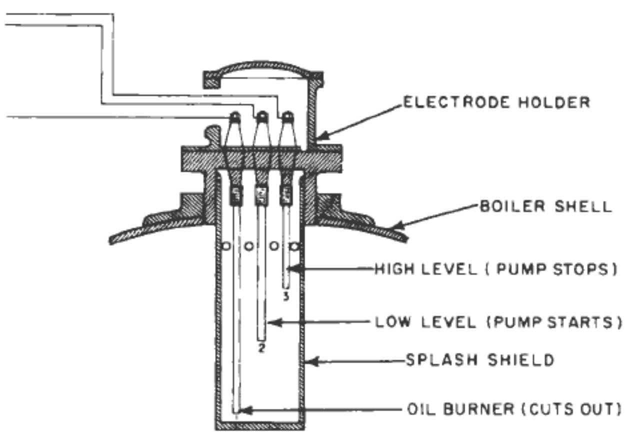
Figure 4-26.—Pressure switch.

SAFETY COMBUSTION CONTROLS

Safety combustion controls are devices designed to shut down the burner and thus prevent flooding the furnace with oil in event of ignition failure or flame failure subsequent to initial ignition. These controls include the thermostatic type (stack switches and pyrostats), photoelectric type, and the photo-conductive type.

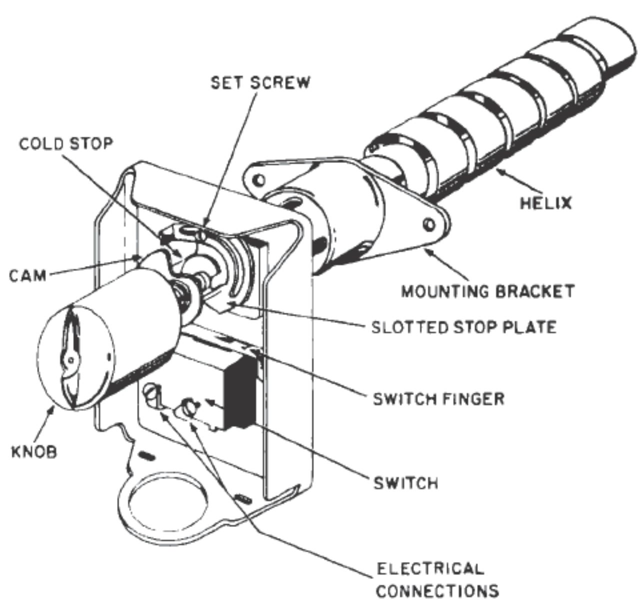


26.185

Figure 4-25.—Water level electrode assembly.

Stack switch (thermostatic type)

The stack switch basically consists of a bimetal helix, a mounting frame, a shaft carrying a contact-making mechanism, and an electric switch. A typical stack switch is shown in figure 4-27. The helix is connected to the mounting frame at one end and a rotating shaft at the other. The stack switch is mounted on the boiler smoke stack or hood with the helix protruding into the path of the combustion gases. The shaft, which is inside the helix, turns a cam which pushes a switch finger which closes a switch. The switch is wired into the burner electric circuit so that no current is supplied to the



26.187

Figure 4-27.—Stack switch.

burner when the contacts are open, except through the protecto relay to permit initial ignition. When there is no heat in the boiler, the switch contacts are open. When the burner is ignited, the helix expands due to the increase of the stack temperature and causes the shaft to rotate and close the contacts. Unless the stack temperature decreases, the contacts remain closed, permitting operation of the burner. In the event of a flame failure, the helix contracts due to the falling stack temperature and causes the shaft to rotate in the reverse direction. This opens the contacts and shuts down the burner.

Photoelectric Combustion Controls

A photoelectric control basically consists of a photoelectric cell, an amplifying unit, and a relay. These controls operate by the luminosity of the flame acting upon the photoelectric cell which makes contact within itself when light rays impinge upon it. The amplified current of the photoelectric cell operates the relay which is wired into the burner control circuit. The relay closes the burner circuit when the flame is established and breaks the burner circuit in event of flame failure.

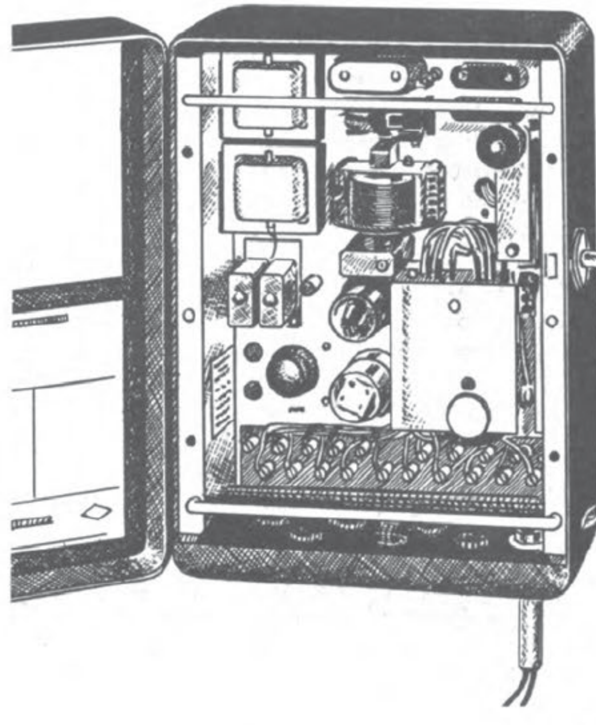
Photo-Conductive Combusion Control

The photo-conductive control (fig. 4-28) serves the same function as the photoelective type. In the photo-conductive type, resistance of the cell varies when exposed to infrared radiation. the associated electronic circuit of the control amplifies only the pulsating frequency peculiar to flame radiation. The control thus discriminates between flame and hot refractory or other source of infrared.

PROTECTORELAYS

A protectorelay is an electromagnetic switch usually consisting of a signal amplifying circuit, three relays, and a thermal safety switch. A schematic of a typical Protectorelay is shown in figure 4-29. Protectorelays are used on many firetube type boilers arranged for automatic operation to perform the following functions:

1. Provide interlock between burner and burner controls.

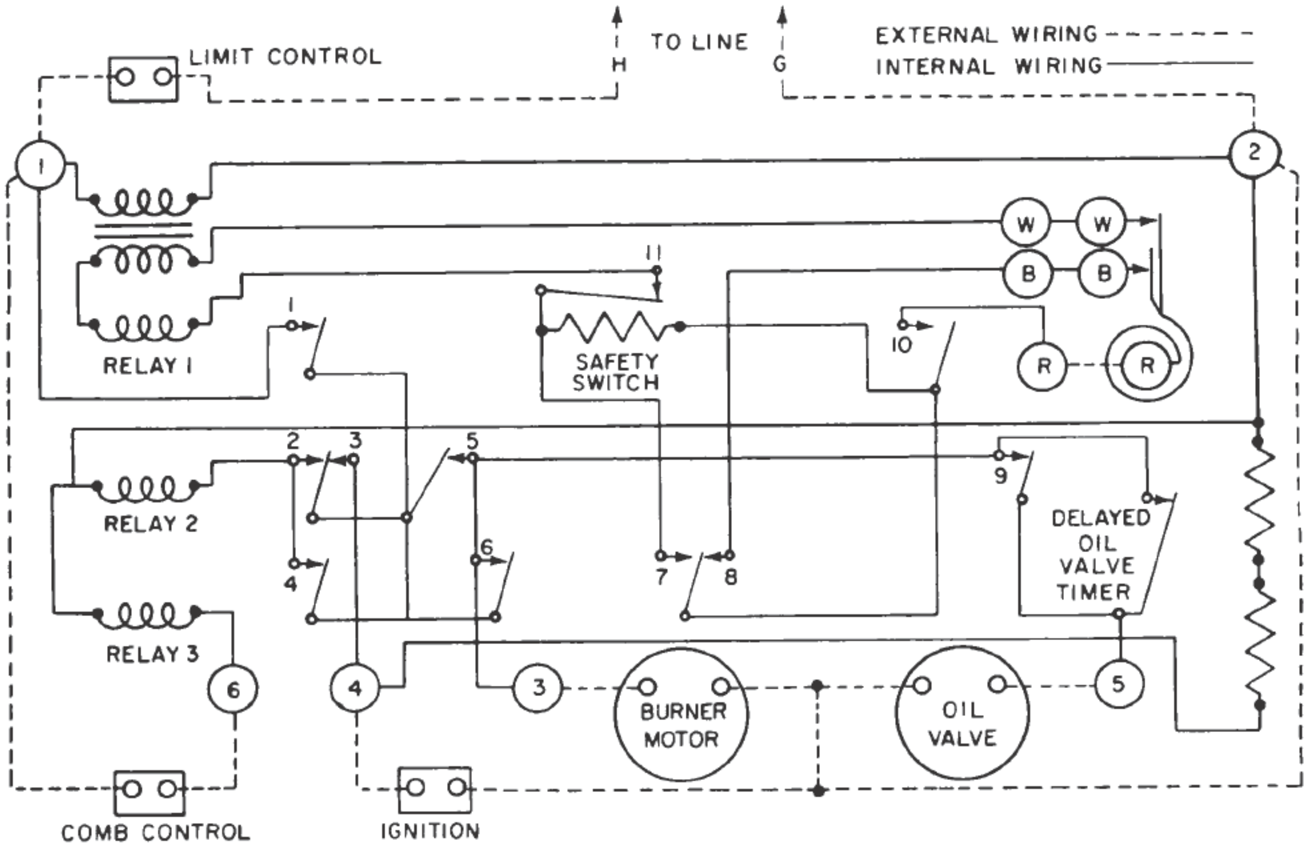


26.188
Figure 4-28.—Fireye combustion control.

2. Provide a temporary circuit for starting burner and ignition.
3. Effect automatic shutdown and restart of burner in response to pressure regulating and feed water regulating controls.
4. Effect emergency shutdown of burner in response to safety combustion controls.
5. As an integrated part of the boiler control circuit, to tie together the burner operating controls and the safety combustion controls.

MAINTENANCE

Because of the wide variations in the design of the boilers which the Seabees operate and maintain it is impractical to prepare general operating and maintenance instructions for all the types in use. Therefore, the Navy requires that manufacturers include this information in their technical manuals which are provided with each boiler. Specific attention should be paid to maintaining automatic regulating, control, and safety devices in proper operating condition. Undetected failure of these devices may lead to



26.189

Figure 4-29.—Drawing of a Protectorelay.

a major casualty, injury to personnel, and damage to equipment.

TROUBLESHOOTING HINTS

There are many hints in troubleshooting that will make it easier for you to find trouble when boilers aren't operating properly. The following lists contain common causes of ignition and flame failure.

A. Ignition Failure

1. Dead transformer.
2. Broken or High Voltage leads.
3. Cracked electrode insulator.
4. Carbon deposits on electrodes or insulators.
5. Incorrect electrode setting.
6. Malfunctioning programming control cams.
7. Faulty ignition cable connector.
8. Solenoid valve fails to open.
9. Water in oil.
10. Dirty or clogged burner tip.

B. Flame Failure

1. Dirty glass in photocell.
2. Abnormal ambient temperature. (Refer to combustion safeguard in boiler technical manual.)
3. Bad electron tube in combustion safeguard control.
4. Bad electron tube in photocell.
5. Damaged cell.
6. Loose connection on photocell.
7. Out of oil or water in oil.
8. Clogged nozzle.
9. Broken belt (V-belt drive).
10. Broken pressure regulator spring.
11. Dead solenoid valve.

CHAPTER 5

TESTING EQUIPMENT

After electrical generating plants, distribution systems, communications systems, and other electrical apparatus and equipment have been constructed and put into operation, they must be tested, inspected, and maintained.

In order to test, inspect and maintain electrical systems and equipment, you must know the principle and operating procedures of the various testing and measuring devices. These devices are used to test for grounds, opens, shorts, and to measure current, voltage, power resistance, frequency, etc.

The purpose of these devices is to test and measure accurately certain circuit values or to determine the operating condition of the electrical circuits. The accuracy of these instruments will depend on the type, sensitivity, useful range, and how they are treated.

POWER TEST EQUIPMENT

Four of the most commonly used electrical testing devices are the ohmmeter, voltmeter, ammeter, and the wattmeter. As you know, the ohmmeter measures the amount of resistance (ohms); the voltmeter measures the amount of voltage (volts); the ammeter measures the amount of current flowing through a conductor (amperes); the wattmeter measures the amount of power being drawn by and electrical device or apparatus (watts).

The principles and theories of the various types of testing and measuring devices are explained in Basic Electricity, NavPers 10086-A and Construction Electrician 3 & 2, NavPers 10636-E, therefore, they will not be repeated in this text.

DUCTER OHMMETER

The ducter ohmmeter (fig. 5-1) is a device that is primarily used to measure very low resistances (0 to 1 ohm) of bus and circuit breaker contacts. It is used to measure connection and contact resistances. It is a direct-reading ohmmeter of rugged construction powered by its own source of low-voltage direct current. For convenience, this source of current can be three dry cells in parallel, except in the lowest ranges when a storage battery cell should be used. The ohmmeter is constructed in such a way that its reading is independent of the applied voltage.

The source of potential is connected so that the current flows through the instrument in series with the circuit to be measured, and the voltage leads of the instrument are connected across the portion of the circuit to be measured (fig. 5-2). The ducter is strictly a field instrument, being accurate only to about 1 percent. It is convenient to use because no current-regulating devices are necessary, the current being whatever the circuit resistance will pass.

In using the ducter ohmmeter to test an oil circuit breaker, the breaker is deenergized and isolated by disconnect switches. The breaker is closed by manual control. A test made for foreign voltage (to assure that the breaker is deenergized), should be followed by application of standard safety grounding. The ducter leads are then placed across the two risers of any one phase, preferably above the top connections to the bushings, as shown in figure 5-3. Readings are obtained similarly for the other two phases.

The following defects, not readily ascertained during overhaul, are typical of conditions that may be disclosed by the use of a ducter ohmmeter:

1. Loose connections at tops of bushings
2. Loose connection between central bushing stud and bushing cap
3. Loose sweated lugs and poor connections under taped joints

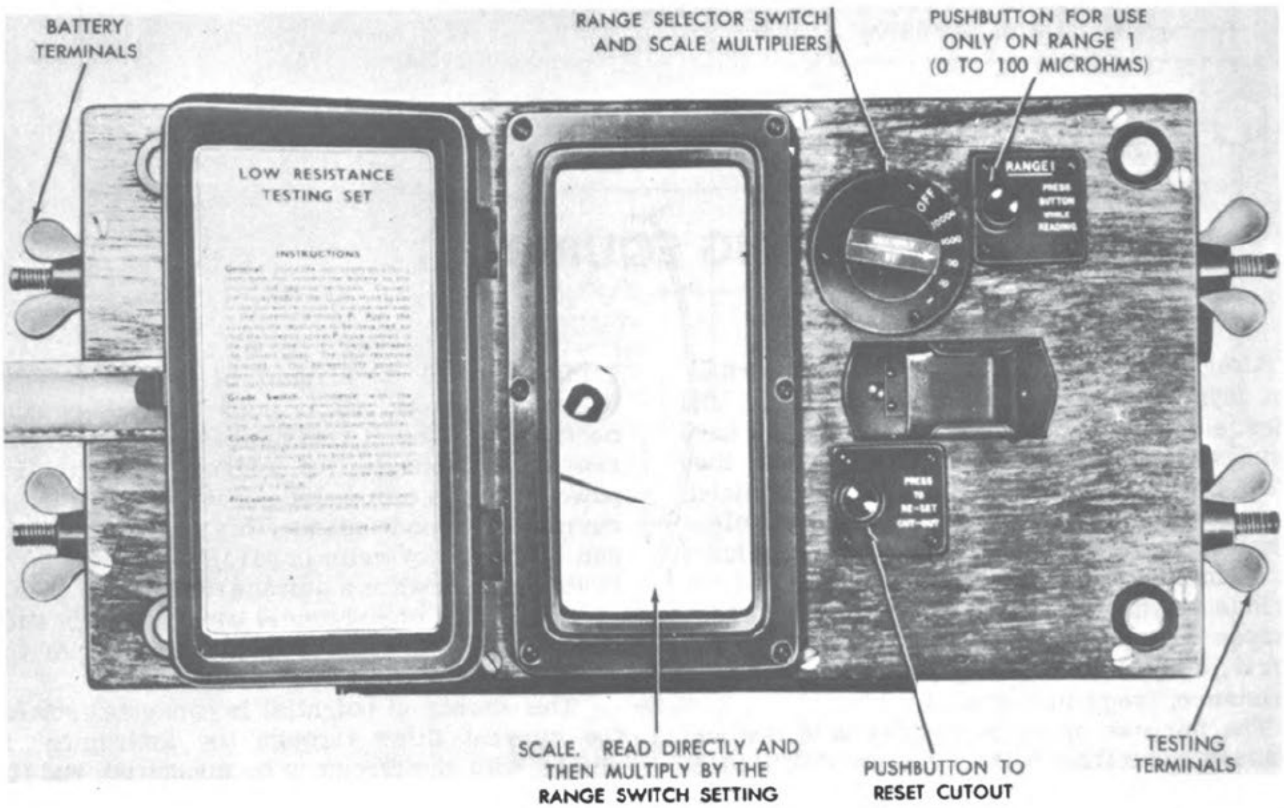


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Figure 5-1.—Ducter ohmmeter (low-resistance).

4. Loose stationary contacts inside explosion chambers and grids
5. Loose arcing contacts
6. Oxidized contact surfaces
7. Cracked bayonet clamps
8. Loose connections inside high-voltage current transformers
9. High-resistance connections on apparatus.

Ducter ohmmeter tests should be made at least every 2 years in conjunction with power-factor tests. When testing low-voltage breakers (15-kv and lower) and readings exceed 5000 to 10,000 microhms, the cause of the high readings should be investigated and corrected.

MEGOHMMETER

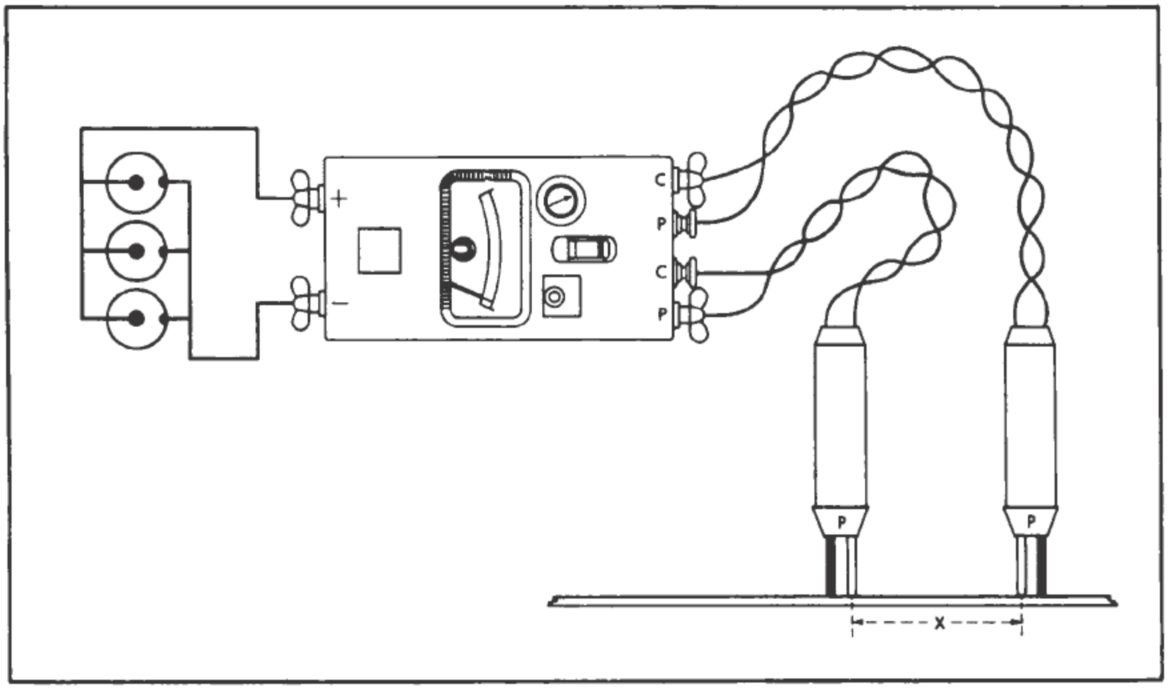
The megohmmeter is a high-range, direct-reading ohmmeter for measuring insulation resistance. This meter is commonly called a megger, and is primarily used for detecting and diagnosing insulation weakness in electric equipment and conductors.

The general procedure for testing substation transformers with a megger is as follows:

1. Open the oil circuit breakers to deenergize the transformer.
2. Open the disconnect switches on both sides of the transformer or transformer bank.
3. Check both sides of each transformer with a voltage detector.
4. Apply ground sticks or ground cables to terminals on both sides of the transformer bank.

CAUTION: Always connect one end of the grounding cable to ground first, then apply the other end of the grounding cable to the bus or metallic terminals of transformers.

5. Place switching tags on open switches.
6. Remove ground sticks to make insulation-resistance test.



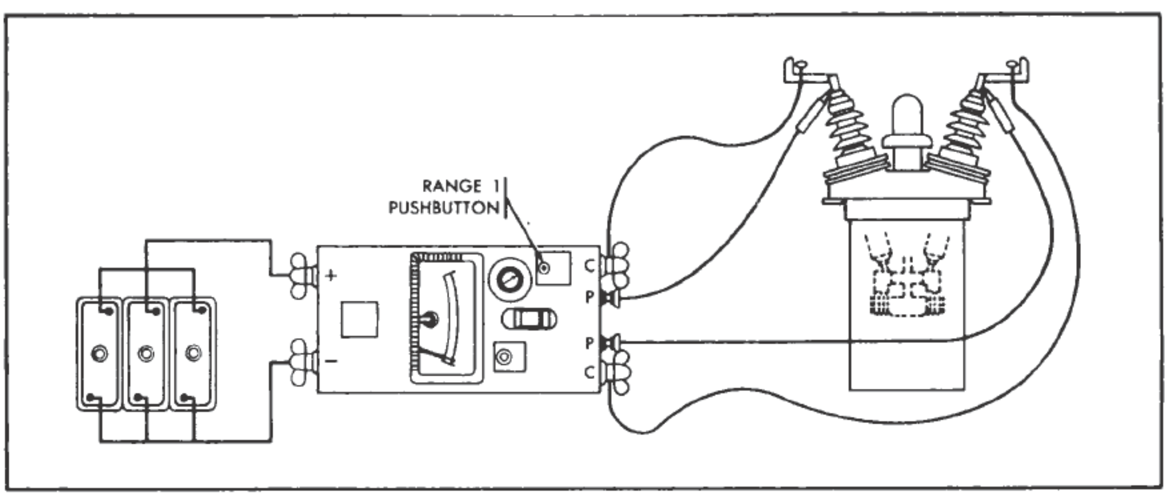
26.27

Figure 5-2.—Ducter testing with duplex helical handspikes.

7. Test the high-voltage and low-voltage windings separately to ground, connecting the line terminals of the windings and the ground terminal of the instrument to the transformer case.

8. Test between the high-voltage and the low-voltage windings.

The test outlined above is an overall test and includes the transformer bushings and other equipment such as bus support insulators. If insulation-resistance values are 2000 megohms or higher, no further tests are needed. If the values are below requirements, external leads should be disconnected and the insulation-resistance test repeated. If the second test



26.28

Figure 5-3.—Ducter testing the contacts of a large circuit breaker.

shows resistance values as being still too low, oil samples should be taken to determine whether or not the low values may be due to deterioration of the oil. If this fails to locate the source or cause of low resistance values, there is no alternative except to remove the bushings and test the insulation of the coils and oil as a single homogeneous component. If the resistance is still too low, then the oil must be drained off and the source of trouble must be sought in the individual coils.

In testing transformers with a megger, the test should be made during clear, dry weather. The temperature and relative humidity of the air and general atmospheric conditions should be recorded at the time tests are being made, if known. Test records should be kept as they show when trouble is developing as a result of gradual or sudden deterioration of the insulation or because of local leakage. For example, a 40-megohm reading on the primary winding of a 24,000/2400-volt transformer that has been testing about 500 megohms indicates trouble that should be remedied.

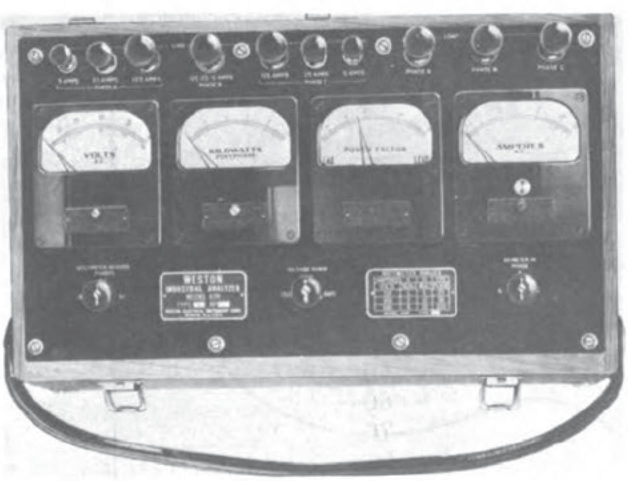
POWER CIRCUIT ANALYZER

Power circuit analyzer or industrial analyzer (fig. 5-4.) is designed for alternating current only and should not be used on direct current.

The analyzer consists of a voltmeter, ammeter, wattmeter, and a power factor meter (fig. 5-5), together with two current transformers and the necessary switches to facilitate the testing of three-phase, 3-wire loads.

Although the analyzer has been designed primarily for three-phase, 3-wire loads it can be used for measurements on single phase and other polyphase circuits.

Before connecting the analyzer, it is advisable to set the voltage range changing switch



26.29
Figure 5-4.—A-C power circuit analyzer.

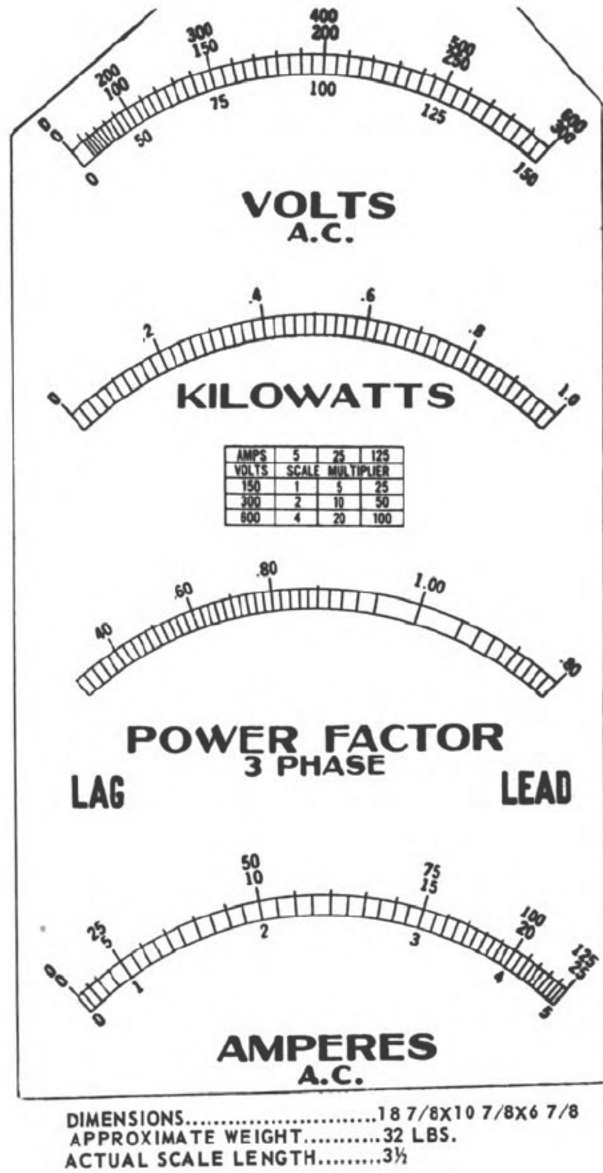


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Figure 5-5.—Scales of the power circuit analyzer.

to the 600 volt range unless the voltage to be measured is definitely known to be suitable for a lower range.

When testing other than a balanced three-phase 3-wire load, the indications of the power factor meter should be disregarded.

The VOLTMETER is of the movable iron type having its series resistance divided with a part connected to each side of the line under test.

Its indications are correct to ± 1 percent of the full scale on any range, at any temperature between 20° and 40° C on any frequency from 25 to 125 cycles per second and on ordinary commercial wave forms.

The WATTMETER is of the electrodynamometer type, having two elements, designed for polyphase or single-phase measurements.

The indications of the wattmeter, together with the transformers contained in the analyzer, are correct to ± 2 percent of the full scale value on any range, at any temperature between 0° and 50° C on any frequency from 25 to 125 cycles per second and on ordinary commerical wave forms.

Multiplying (resistance) factors for the scale reading, depending on the current and potential ranges used, are to be found on the wattmeter scale.

The POWER FACTOR METER is of the crossed coil electrodynamometer type designed for balanced three-phase 3-wire loads.

Its indications are correct to .01 PF when connected to a three-phase 3-wire balanced load so that the phase rotation is A-B-C, at any temperature between 0° and 50° C at any frequency from 25 to 125 cycles per second, and on ordinary commercial wave forms. This same accuracy is maintained when the current is within 20 to 125 percent of the normal rating; that is, 1 to 6.25 amperes on the low range, 5 to 31 amperes on the medium range, and 25 to 156 amperes on the high range.

As mentioned previously, when the analyzer is connected to a single-phase, two-phase, or three-phase 4-wire loads the indications of the power factor meter should be disregarded.

The AMMETER is of the movable iron vane type designed for use with the current transformers contained in the analyzer.

The indications of the ammeter, together with the transformer contained in the analyzer, are correct within ± 1 percent of the full scale value at any temperature 10° to 40° C at any frequency from 25 to 125 cycles per second and on ordinary commercial wave forms.

Independent of the transformers, the ammeter has a full scale range of 1 ampere. The scale is expanded in the center and contracted at each end. This characteristic is useful for motor testing.

CONNECTING ANALYZER TO CIRCUITS

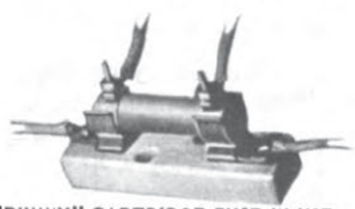
All cables used for connections to source or load should be of sufficient size to carry the currents involved and connected securely to the binding posts and the circuit terminals. For current up to 125 amperes use No. 2 cable; for currents up to 25 amperes use No. 12 cable; current up to 5 amperes use No. 16 cable. For more data pertaining to cables see table 5-1.

The most convenient place to make connections is at the fuse block, by using dummy fuses with cables attached (fig. 5-6). The cables

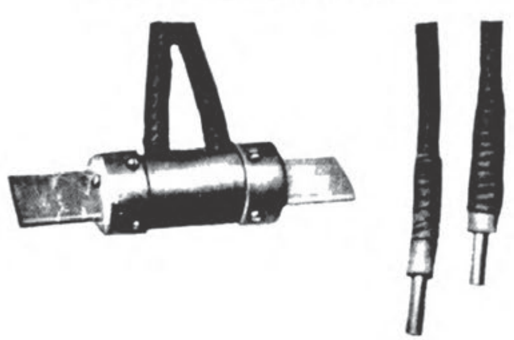
Table 5-1.—Allowable Carrying Capacities of Copper Wires (Single conductor in free air)

B.S. Gauge	Area in Circular Mills	Amperes
14	4,107	20
12	6,530	25
10	10,380	40
8	16,510	55
6	26,250	80
4	41,740	105
3	52,630	120
2	66,370	140
1	83,690	165
0	105,500	195
00	133,100	225
000	167,800	260
0000	211,600	300
-	250,000	340
-	300,000	375
-	350,000	420
-	400,000	455
-	500,000	515
-	600,000	575
-	700,000	630
-	800,000	680
-	900,000	730
-	1,000,000	780

VARIOUS TYPES OF CUT-OUT FUSES FOR MEASURING CURRENT WITHOUT INTERRUPTING SERVICE



"DUMMY" CARTRIDGE FUSE IN USE



26.31X
Figure 5-6.—Various types of "dummy" fuses.

connected to these dummy fuses may be connected to the analyzer. When an interruption to service will be inconvenient, it is only necessary to remove the good fuses from the cutout and insert the dummy fuses with cables attached.

CAUTION: Disconnect the circuit by opening the main line switch before removing fuses and inserting dummy fuses. This may be done very quickly. This method is only a suggestion and may not always be practical. When using this method be certain that the circuit is protected by other fuses or circuit breakers as these dummy fuses remove the protection at that point.

Testing Single-Phase Loads

The diagrams of connections shown in figures 5-7, 5-8, and 5-9 may be used for all 2-wire circuits.

Note in the figures mentioned above that a connection is made on the analyzer from the C to the A phase, by means of which both elements of the wattmeter are used. This is done to get as great a deflection of the wattmeter movement as possible. This is not essential as the wattmeter readings are correct regardless of whether one or both elements are used. If only one element of the wattmeter is used, the divisor of two should be omitted.

For single-phase, 3-wire circuits the connections are the same as the three-phase, 3-wire connections.

Three-Phase 3-Wire Loads

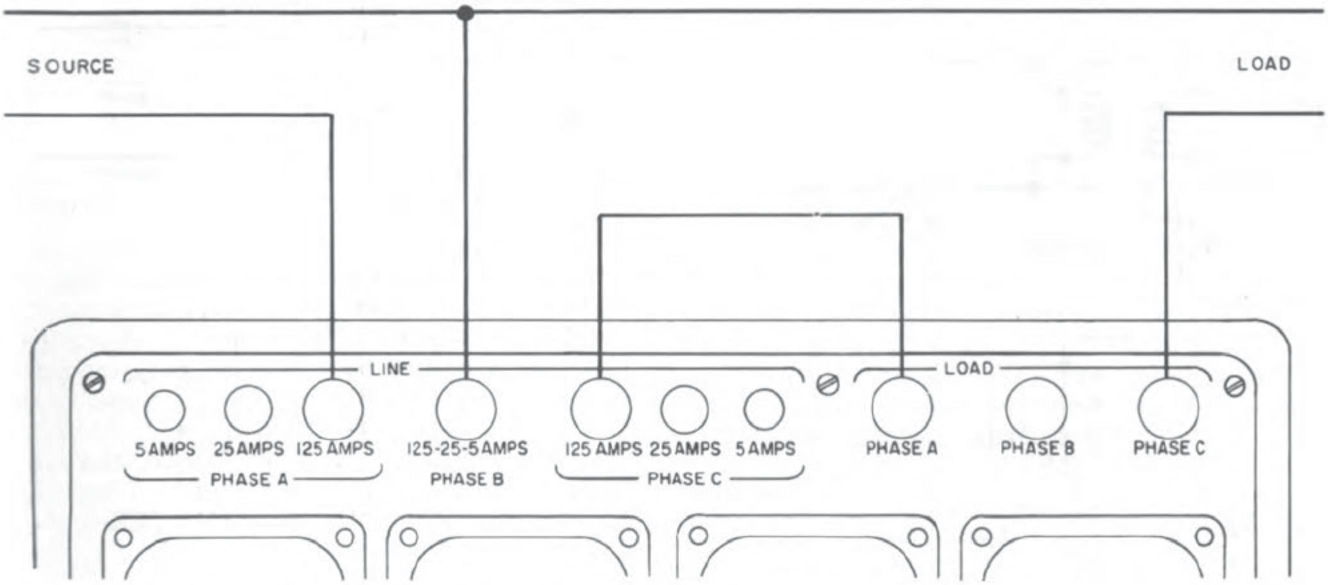
Figures 5-10 and 5-11 show the connections necessary for all three-phase, 3-wire testing. The readings of the wattmeter are correct regardless of unbalance or power factor of the load. The readings of the power factor meter are correct for any current down to 1/5 of the full scale value.

Three-Phase 4-Wire Loads

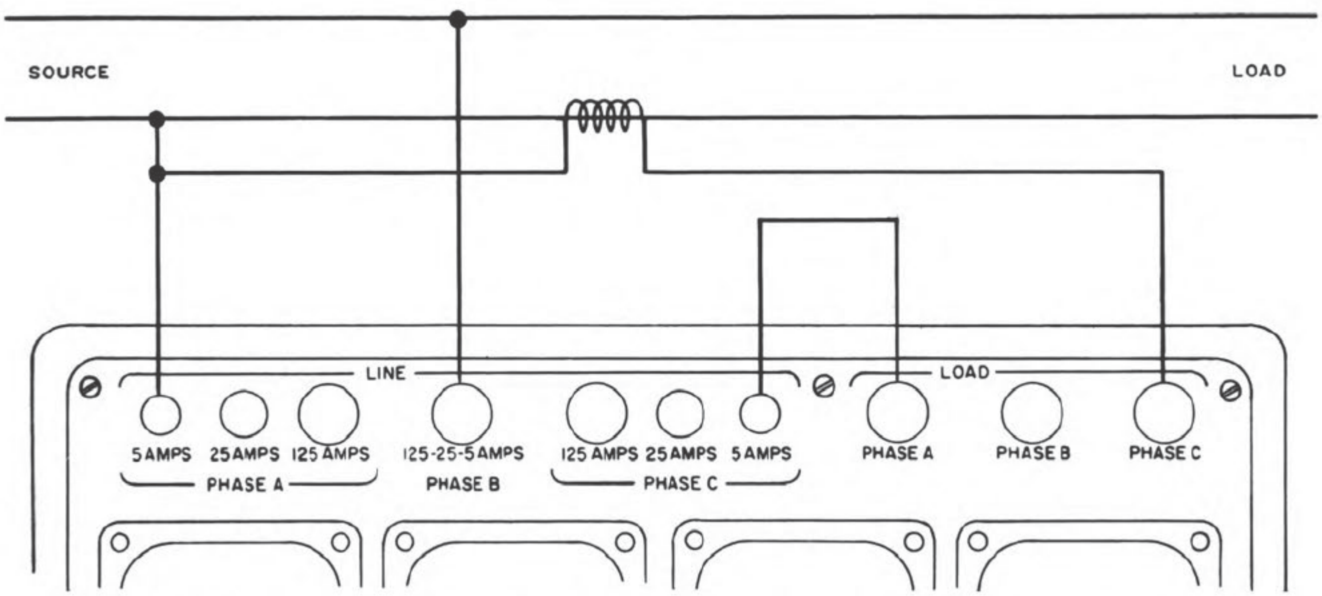
As mentioned earlier, the analyzer was designed primarily for three-phase, 3-wire loads, therefore, when three-phase 4-wire loads are to be analyzed certain limitations are to be expected.

1. The power factor meter has been designed for balanced three-phase, 3-wire loads. Its readings on three-phase 4-wire loads should be disregarded.
2. The voltmeter readings will be "line to neutral" and "line to line" voltages depending upon position of voltage selector switch.
3. External current transformers must ALWAYS be used. (See fig. 5-12.)

If the three-phase 4-wire load is balanced, with no current in the neutral wire, it may treated as outlined for a three-phase 3-wire load and the above limitations should be disregarded.



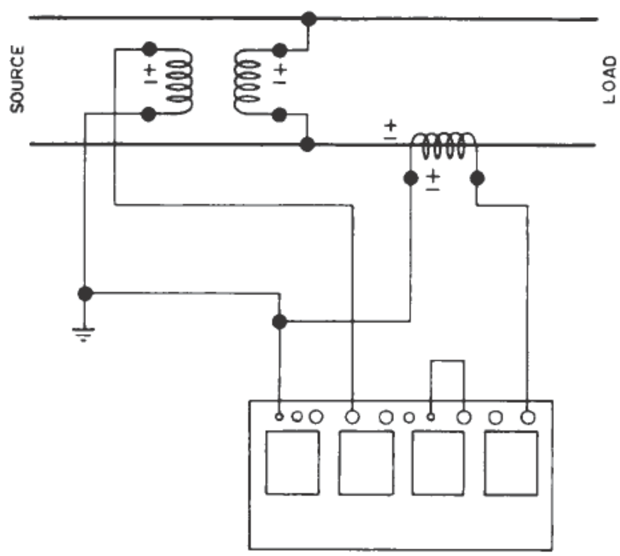
A. SINGLE PHASE, 2 WIRE CIRCUIT, both elements of wattmeter in series. Read voltage AB, current A, apply the wattmeter multiplier as found on the wattmeter scale and then divide by 2. Disregard the power factor indication.



B. SINGLE PHASE, 2-WIRE CIRCUIT using a single current transformer and with two current elements in series, read voltage AB and current A using 5 ampere scale and applying transformer multiplier. Divide kilowatt reading on 5 ampere and corresponding voltage scale by 2; then apply transformer multiplier. Disregard power factor indication.

26.32

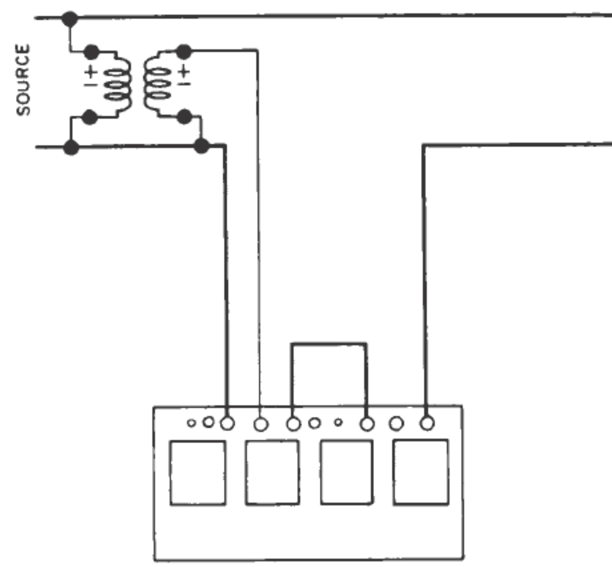
Figure 5-7.—Single-phase, 2-wire circuit, both elements of wattmeter in series.



SINGLE PHASE, 2-WIRE CIRCUIT using a current transformer and a potential transformer, the current elements of the analyzer in series, read voltage AB using 150 volt range and scale, multiply by potential transformer ratio, current A using 5 ampere scale and applying current transformer ratio. Read kilowatts on scale corresponding to 5 amperes and 150 volts then divide by 2 and multiply by current and potential transformer ratios.

26.33

Figure 5-8.—Single-phase, 2-wire circuit using a current transformer and a potential transformer.



SINGLE PHASE, 2-WIRE CIRCUIT using a potential transformer and direct connected for the current circuits with the current elements in series. Read voltage AB using 150 volt scale and range, multiply by transformer ratio. Read kilowatts on scale corresponding to 150 volts and current range selected, divide by 2 and multiply by the potential transformer ratio. Read current A using scale corresponding to range selected.

26.34

Figure 5-9.—Single-phase, 2-wire circuit using potential transformer and with current elements in series.

Regardless of the balance each phase may be treated as a single-phase load and tested accordingly.

In using the external current transformers, they should have the same ranges as the transformers contained in the analyzer, that is 125, 25, or 5 amperes.

The readings of the voltmeter, using proper range and scale, represent the following:

With switch at AB, the voltage from line A to neutral.

With switch at BC, the voltage from line C to neutral.

With switch at AC, the voltage from the line A to line C.

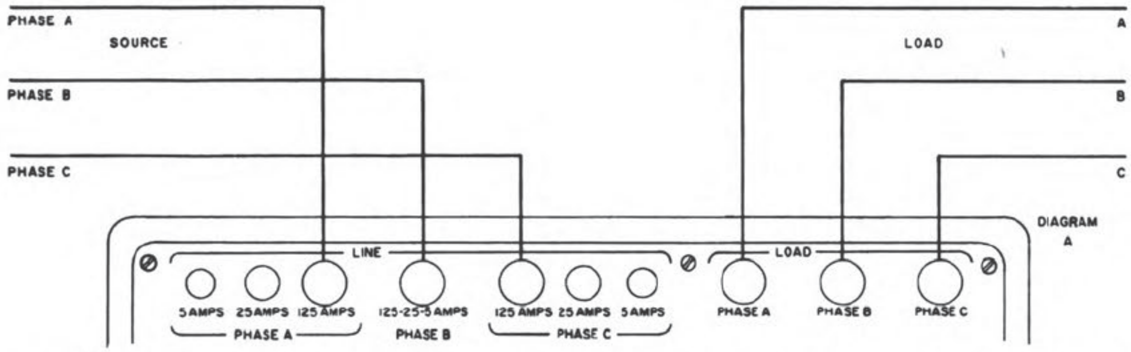
The wattmeter readings must be corrected by the multiplying factors found on the wattmeter scale.

When external potential transformers are used, as shown in figure 5-13, the readings of the voltmeter and wattmeter should be multiplied by the potential transformer ratio in addition to the above.

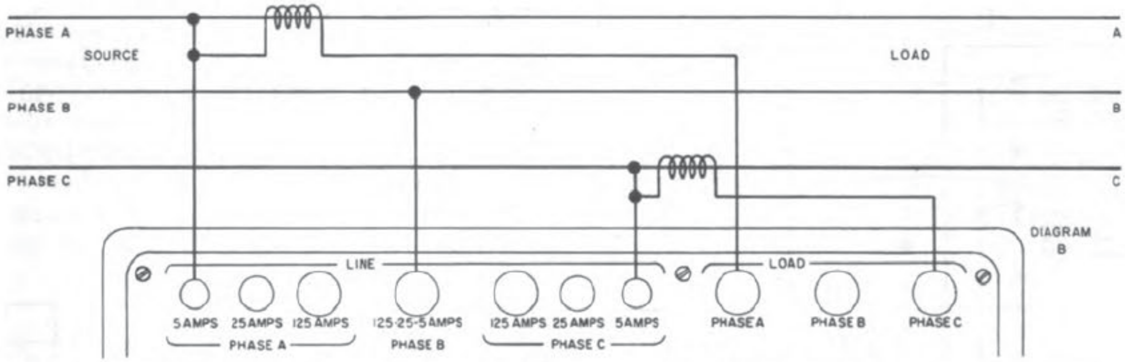
When currents to be measured are beyond the range of the internal current transformers the connections shown in figure 5-14 should be used.

The readings of the voltmeter, using proper range and scale, represent the following:

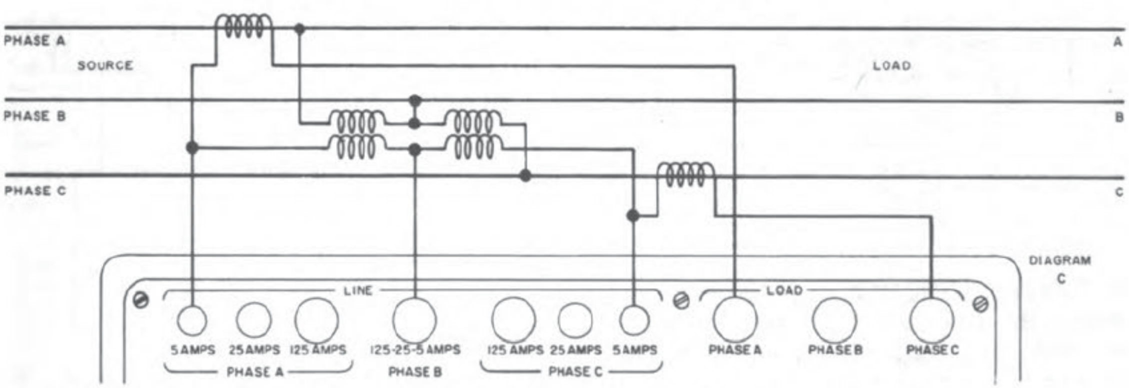
With switch at AB, the voltage from line A to neutral.



A. **3 PHASE, 3 WIRE CIRCUIT direct.** Read voltage across phases as desired as well as current in any phase. Apply multiplier as given on wattmeter scale to reading as necessary for voltage and current range used. Read power factor direct.



B. **3-PHASE, 3-WIRE CIRCUIT** with two current transformers. Read voltage across phases as desired and current in any wire, applying transformer multiplier to 5 ampere scale on ammeter. Apply transformer multiplier to wattmeter, also multiplying by multiplier of 1, 2 or 4, depending upon voltage range as indicated on wattmeter scale. Read power factor direct.



C. **3-PHASE, 3-WIRE CIRCUIT** using both current and potential transformers. Read voltage across phases as desired applying potential transformer multiplier to 150 volt scale to which the voltage range switch should be set. Read ammeter in any phase applying current transformer multiplier to 5 ampere scale. Read polyphase wattmeter on 1 kilowatt scale and apply both current and potential transformer multipliers. Read power factor direct.

26.35

Figure 5-10.—Three-phase, 3-wire circuit, diagram A, B, and C.

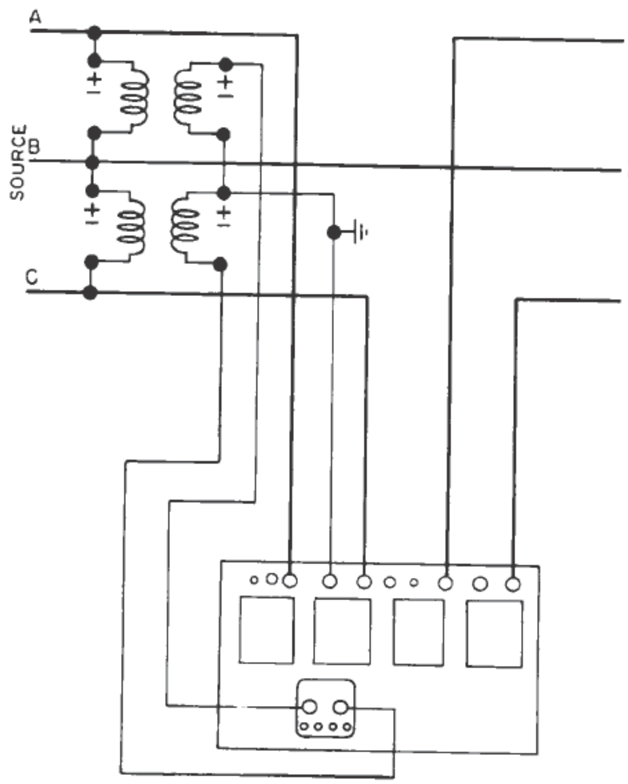
With switch at BC, the voltage from line C to neutral.

With switch at AC, the voltage from line A to line C.

The wattmeter readings must be corrected by the multiplying factors found on the wattmeter scale and the external current transformer ratios.

Potential connections from lines A and C are connected to the disconnect block binding posts, with the block mounted with the binding posts up.

When external potential transformers are used, as shown in figure 5-15, the readings of the voltmeter and wattmeter should be multiplied by the potential transformer ratio in addition to the above.



3-PHASE, 3-WIRE CIRCUIT with two potential transformers. Read voltage across phase as desired, use 150 volt range and apply potential transformer ratio. Read ammeter in any phase direct for range selected. Read wattmeter scale, use multiplying factor for current and potential ranges selected, then multiply by potential transformer ratio.

26.36

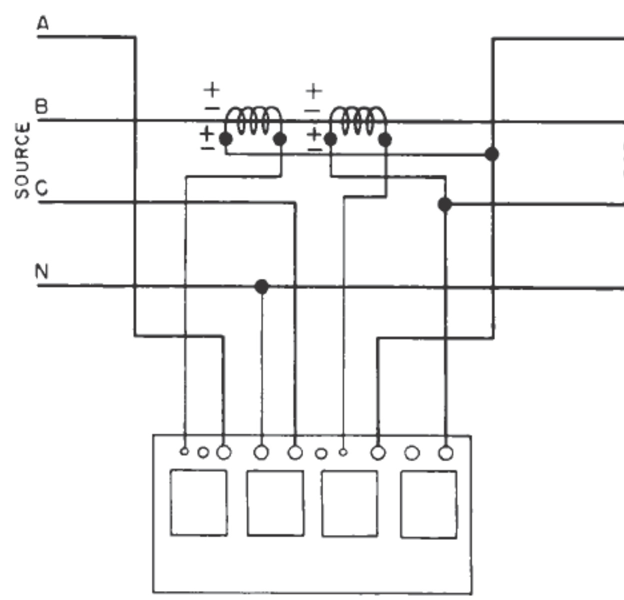
Figure 5-11.—Three-phase, 3-wire circuit with two potential transformers.

TRANSFORMER POLARITY TESTS

Polarity has to do only with the plan or arrangement of leads coming out of a transformer case. Interchanging the positions of the leads coming out of the case will affect the polarity of the transformer.

On a transformer wound with additive polarity, where one primary lead is connected to a secondary lead on the same side of the case as shown in figure 5-16, the voltage in the two windings is additive; that is, the sum of the applied and secondary voltages will be indicated on a voltmeter connected across X_1 and H_2. On a transformer wound with subtractive polarity, the indication on the voltmeter will be the difference of the applied and secondary voltages.

Polarity may be determined, for example, by applying 120 volts to the high-voltage side of a 10 to 1 ratio transformer. Referring to figure 5-16, V_s or the secondary voltage would equal 12 volts. With an additive polarity transformer, a voltmeter across X_1 and H_2 should read V_p



3-PHASE, 4-WIRE CIRCUIT. Two identical current transformers of suitable range having 5 ampere secondaries are connected in the "B" phase as shown.

26.37

Figure 5-12.—Three-phase, 4-wire circuit having two identical current transformers.

ılus V or 120 plus 12, which equals 132 volts. Vith subtractive polarity transformer, a volneter across X_1 and H_2 would read 120 minus .2 or 108 volts.

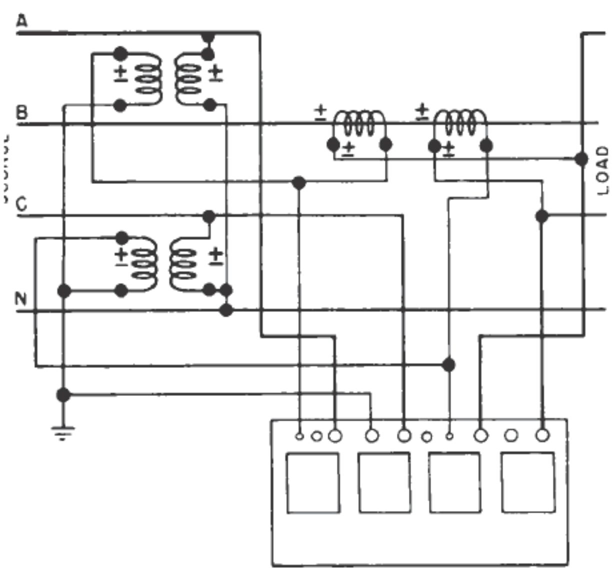
CAUTION: When making such tests, voltage nust not be applied across the secondary side of he transformer because the primary voltage vould be equal to the applied secondary voltage imes the transformer ratio. This voltage would ›e dangerously high to personnel and would burn ›ut the voltmeter. Figure 5-17A and B illusrates two practical methods for testing polarity.

COMMUNICATIONS TEST EQUIPMENT

There are various testing instruments used or checking out communication circuit and ·quipment. However, in this chapter we will liscuss the portable WHEATSTONE BRIDGE and he CABLE REPAIRMAN'S test set.

VEATSTONE BRIDGE

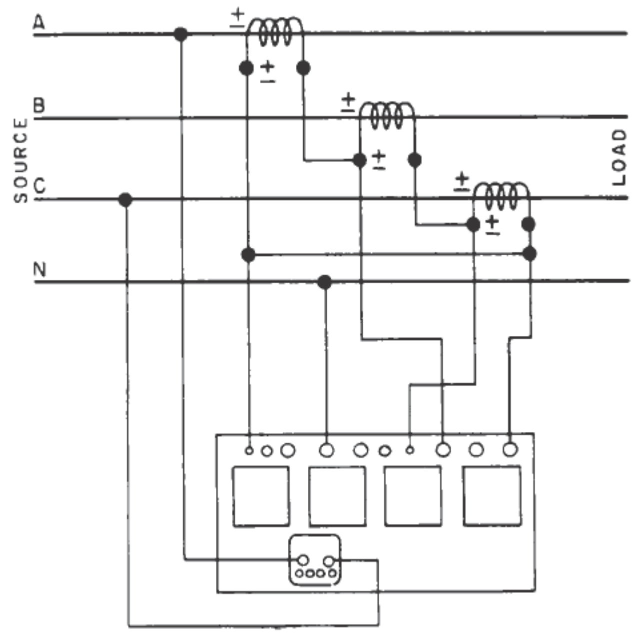
The Wheatstone bridge (fig. 5-18A) is used to ıccurately measure the resistance of electrical



ı-PHASE, 4-WIRE CIRCUIT. Two potential ransformers having 115 volt secondaries, conıected from neutral to lines "A" and "C". Γwo current transformers of suitable range ıaving 5 ampere secondaries.

26.38

Figure 5-13.—Three-phase, 4-wire circuit with two potential transformers.



3-PHASE, 4-WIRE CIRCUIT. Potential direct connected. Three current transformers of suitable range having 5 ampere secondaries delta connected.

26.39

Figure 5-14.—Three-phase, 4-wire circuit with potential directly connected.

circuits. The basic bridge has 4 arms (A, B, R, and X). A battery energizes the bridge via S1. A central zero galvanometer is connected across opposite corners of the bridge via S2 to indicate when the bridge is balanced. The ratio arms are A and B. The variable resistance arm is R. The unknown resistance is X. When the bridge is balanced, the voltage across A is equal to the voltage across B and

$$X = \frac{A}{B} R.$$

Knowing A/B and R and substituting in the equation you will find the value of the unknown resistance X.

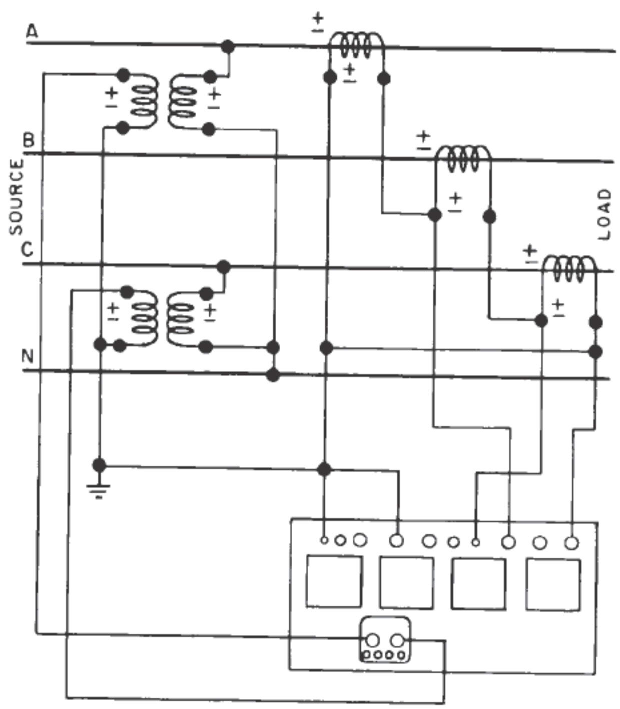
The Wheatstone bridge (fig. 5-18, B and C) may be used to measure the resistance (Res) of a pair of wires in a telephone cable. It may also be used to locate the distance to a fault (ground) in the cable by either of two methods, the Varley (Var) loop test or the Murray (Mur) loop test.

Before using the Wheatstone bridge it is important that you place it on a level surface as near as practicable to the test point, then make the following operational test:

1. Position the following controls as indicated:

   a. GA switch to RVM.
   b. RES-VAR-MUR switch to RES.
   c. MULTIPLY BY dial to 1/1.
   d. Units, hundreds and thousand decade dials to 0.
   e. Tens decade dial to 5.

2. Connect a jumper across line binding posts X1 and X2.



3-PHASE, 4-WIRE CIRCUIT. Two potential transformers of suitable range having 115 volt secondaries connected from neutral to lines "A" and "C". Three current transformers of suitable range having 5 amperes secondaries connected in delta.

26.40
Figure 5-15.—Three-phase, 4-wire circuit connected to three current transformers.

3. Press the GA SENS .01 switch and release it immediately. If the pointer of the galvanometer deflects to the left (—) and returns to zero, the test set is ready for use. If the pointer deflects to the right (+), reverse the polarity of the power source. If the pointer does not deflect in either direction, the test set is faulty and maintenance is required.

MEASUREMENT OF UNKNOWN RESISTANCE

To measure the resistance of a loop (two lengths of wire joined at the distant end) or any electrical component (such as resistors and transformers) do the following:

1. Galvanometer adjustment. Adjust the galvanometer by sliding the pointer lock toward the meter scale as far as it will go. If the pointer does not balance at the center of the scale, loosen the galvanometer screw, located on the side of the zeroing knob, adjust the zeroing knob until the pointer balances at the center of the scale, and tighten the galvanometer screw.
2. Position the test set controls as follows:

   a. GA switch to RVM.
   b. RES-VAR-MUR switch to RES.
   c. Make as close an estimate as possible of the resistance to be measured and set the MULTIPLY BY dial as indicated in table 5-2.

Table 5-2.—MULTIPLY BY Dial Setting When Measuring Resistance

Estimated Resistance (ohms)	MULTIPLY BY dial setting
Below 10	$\frac{1}{1000}$
10 to 100	$\frac{1}{100}$
100 to 1000.	$\frac{1}{10}$
1000 to 10,000.	$\frac{1}{1}$
10,000 to 100,000.	$\frac{10}{1}$
100,000 to 1,011,000.	$\frac{100}{1}$

3. Make the following connections:

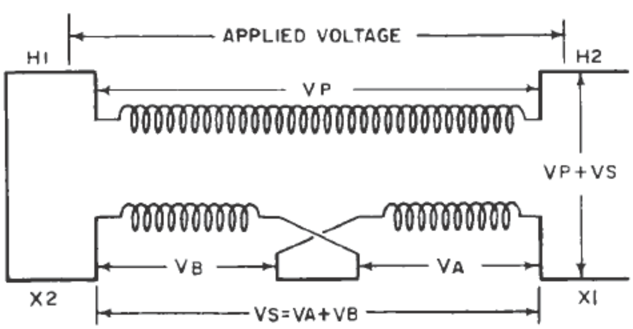
a. If the resistance of a loop is to be measured, disconnect all equipment from the near end of the loop and connect one wire of the loop to line binding post X1 and the other wire to line binding post X2 (fig. 5-19). Be sure that the wires connected to the test set are clean and are firmly secured to the binding posts. Have all equipment disconnected from the far end of the loop and a short placed across the circuit at that end. If the resistance of an electrical component is to be measured, connect the component across line binding posts X1 and X2.

4. To balance the bridge, position the thousands, hundreds, tens and units decade dials to settings that total the estimated resistance to be measured divided by the setting of the MULTIPLY BY dial.

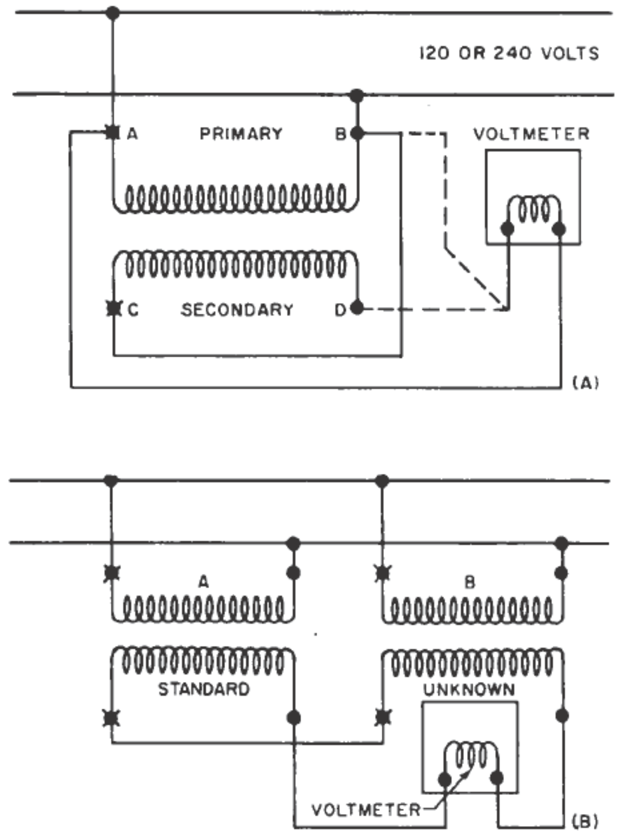
EXAMPLE: If the estimated resistance to be measured is 500 ohms, the setting of the MULTIPLY BY dial must be $\frac{1}{10}$ (table 5-3); therefore the positions of the decade dials must total 5000.

$$\frac{\text{Estimated resistance to be measured}}{\text{Setting of MULTIPLY BY dial}} = \frac{500}{\frac{1}{10}} = 5000$$

Press the GA SENS .01 switch and note the direction of movement of the galvanometer pointer. If it moves to the right, increase the resistance total of the decade dials until it does not move from zero when the GA SENS 0.1 switch is pressed. If the pointer moves to the left, decrease the resistance total of the decade dials. Repeat the above procedure,



26.41
Figure 5-16.—Polarity test example for additive polarity.



A. Voltage measured from A to D is greater than voltage from A to B if polarity markings are correct.

B. Voltage measured across two unmarked terminals equals zero if polarity markings are correct. Otherwise, measured voltage is twice normal secondary voltage.

26.42
Figure 5-17.—More practical methods for testing polarity.

using the GA SENS .1 and then the GA SENS 1 switches. The test procedure is complete when the GA SENS 1 switch is pressed and the pointer does not move in either direction. Under these conditions, the bridge circuit in the test set is said to be balanced.

5. To determine the resistance, take the sum of the decade dial settings multiplied by the setting of the MULTIPLY BY dial.

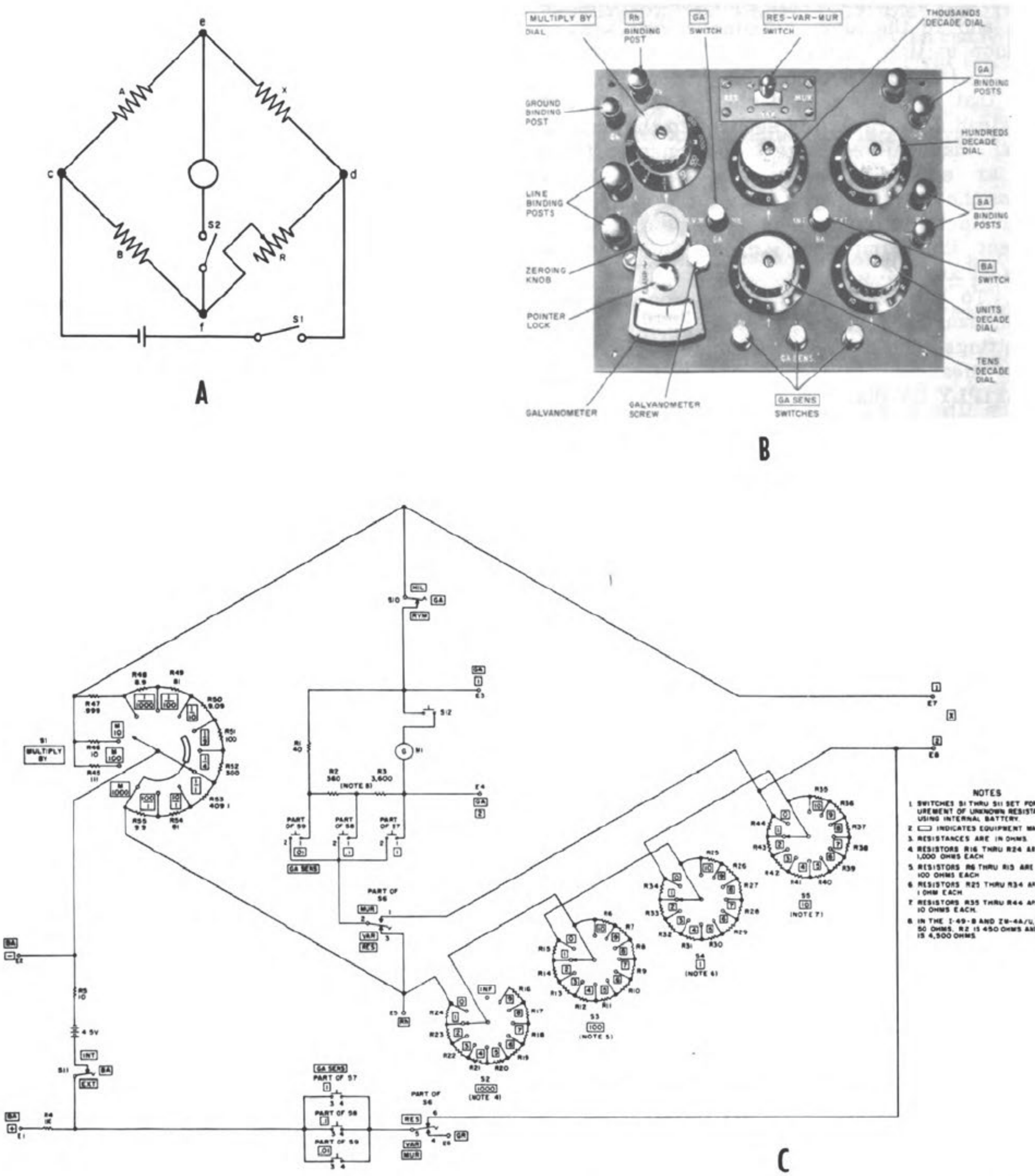
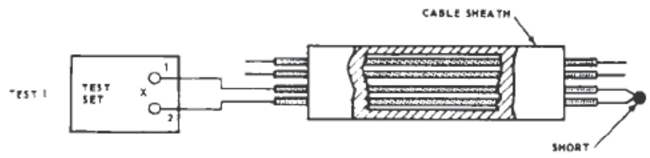
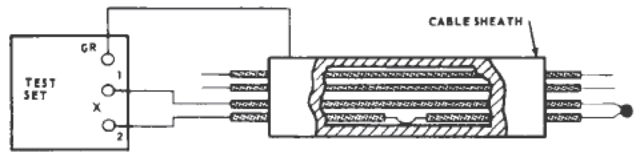


Figure 5-18.—Wheastone Bridge
A. Basic bridge circuit.
B. Operating controls.
C. Schematic.

26.43



26.44
Figure 5-19.—Connection for measurement of loop resistance.



26.45
Figure 5-20.—Connections for ground location, regular Varley and Murray loop tests.

EXAMPLE: If the bridge is balanced when the sum of the decade dial settings is 5137 and the MULTIPLY BY dial is set at $\frac{1}{10}$, the resistance connected across the line binding posts is 5137 x 1/10 or 513.7 ohms (decimal point moved one place to left). If the MULTIPLY BY dial is set at 1/100, move the decimal point two places to the left (51.37 ohms); for 1/1000, move the decimal point three places to the left (5.137 ohms). For 10/1, add one zero to the reading (51,370 ohms) and for 100/1, add two zeroes (513, 700 ohms).

REGULAR VARLEY LOOP TEST

The regular Varley loop test (fig. 5-20) is used to locate a ground in a high-resistance loop when the unbalance (difference in resistance between the faulty and good wires) does not exceed 1 ohm. The regular Varley method requires the use of one good wire between the test point and the far end of the circuit.

Locate the ground as follows:

1. Adjust the galvanometer and remove all equipment from both ends of the faulty circuit.
2. Measure and record the loop resistance, r. In this example assume r = 5525 ohms.
3. Position the test set controls as follows:

   a. Ga switch to RVM
   b. RES-VAR-MUR switch to Var
   c. Multiply By dial to 1/4

4. Make the following connections:

   a. Connect the ground binding post to a good ground connection (fig. 5-20). This will be the cable sheath since the fault is assumed to be in lead covered cable.
   b. Connect the grounded wire to line binding post X2.
   c. Connect the ungrounded wire to line binding post X1.
   d. Have a short placed across the far end of the grounded circuit (fig. 5-20).

5. Adjust the decade dials to balance the bridge and record the sum of the decade dials, R. In this example assume R = 9560 ohms.
6. Compute the resistance X_a from test point to ground fault (fig. 5-21A) using the following formula:

$$X_a = \frac{rB-AR}{A+B}$$

   a. In this example r = 5525 ohms

$$A/B = 1/4$$
$$A = 1$$
$$B = 4$$
$$R = 9560 \text{ ohms}$$

Substituting these values in the formula

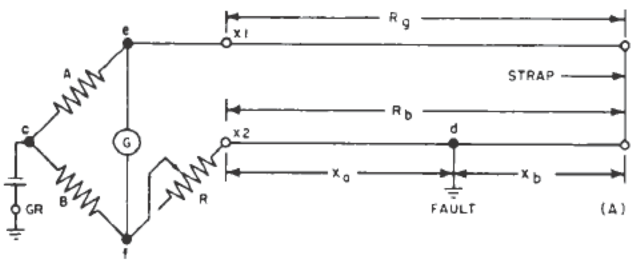
$$X_a = \frac{5525x4-1x9560}{1+4}$$

$$= \frac{22{,}100-9560}{5}$$

$$= \frac{12{,}540}{5} \quad 2508 \text{ ohms}$$

   b. Compute the resistance X_b from the far end to the ground fault using the formula,

$$X_b = \frac{A\ (R+R_b)\ -BR_g}{A+B}$$



26.46.1
Figure 5-21A.—Regular Varley loop test circuit, simplified schematic diagram.

In this example A = 1, B — 4, $R_b = R_g = \frac{r}{2} = \frac{5525}{2} = 2762.5$ ohms and R = 9560 ohms.

Substituting these values in the above formula,

$$X_b = \frac{1(9560+2762.5)-4x2762.5}{1+4}$$

$$= \frac{12{,}322.5-11.050}{5}$$

$$= \frac{1272.5}{5} = 254.5 \text{ ohms}$$

7. Compute the distance d_a from the test set to the fault using the formula:

a. $$d_a = \frac{X_a}{1/2 \text{ resistance per loop mile}}$$

Where resistance per loop mile

$$= \frac{r}{\text{distance from test set to far end}}$$

In this example r = 5525 ohms, and distance from test set to far end = 65 miles

Resistance per loop mile $= \frac{5525}{65} = 85$ ohms

$$X_a = 2508 \text{ ohms}$$

Substituting these values in the above formula,

$$d_a = \frac{2508}{1/2x85}$$

$$= \frac{2508}{42.5}$$

=59.01 miles from test set to ground fault.

b. Compute the distance d_b in miles from the far end to the ground fault using the formula

$$d_b = \frac{X_b}{1/2 \text{ resistance per loop mile}}$$

In this example X_b = 254.5 ohms (from 6_b above) the resistance per loop mile is 85 ohms (from 7_a). Substituting these values in the above formula and solving for d_b

$$d_b = \frac{254.5}{1/2x85}$$

$$= \frac{254.5}{42.5} = 5.99 \text{ miles}$$

8. Make a check on your work as follows:

a. Reverse the wires connected to X1 and X2 of figure 5-20.

b. Adjust the decade dials to balance the bridge and record the sum, R_2, of the decade dials. Use the following formula to determine the resistance X_a from the test point to the ground.

$$X_a = \frac{A(R_2+r)}{A+B}$$

In this example R_2 = 7015 ohms.

A = 1, B = 4, r = 5525 ohms

Substituting these values in the above formula and solving for X_a,

$$X_a = \frac{1x(7015\ \ 5525)}{1+4}$$

$$= \frac{12,540}{5} = 2508 \text{ ohms same as 6(a) above}$$

THREE VARLEY TEST

This test has a definite advantage, especially for central desk testing, over other types of tests in that the resistance of the test cords and the conductors themselves neither need to be known nor allowed for in the calculations. Its chief drawback lies in the fact that a good pair (two conductors of any resistance) are needed in addition to the faulty conductor and ground. Note: (Lead wires and conductors may be of unequal resistance, because this method balances out their resistances.)

The test derives its name from the Varley Loop and from the fact that three such tests must be made. However, each is simple as shown in the diagrams and any tester who can perform the simple Varley need not fear this method. (See fig. 5-21B (a), (b), (c), and (d).)

Set the RES-VAR-MUR switch to VAR. The RVM-GA-HIL switch to R.V.M.

The three tests made are known as "Varley 1", "Varley 2" and "Varley 3", using the connection as shown in figure 5-21B (a), (b), and (c).

The ratio (multiply by dial) A/B must be the same in each test (i.e. 1/1 or 1/4 or 1/9). In using the three (3) Varley Test use 1/1, 1/4, and 1/9 for simplicity.

$$1/1 = A/A+B = 1/1+1 = 1/2$$

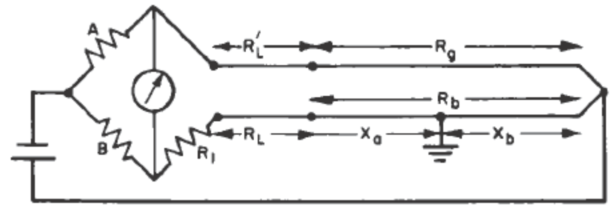
$$1/4 = A/A+B = 1/1+4 = 1/5$$

$$1/9 = A/A+B = 1/1+9 = 1/10$$

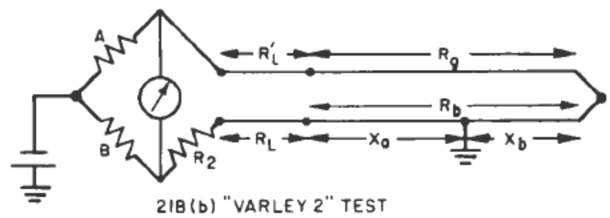
Calling the reostat readings at balance R1, R2, and R3 respectively, the basic equations are:

$$\frac{A}{B} = \frac{R'L+Rg}{R1+RL+Rb} = \frac{R'L+Rg+Rb-X2}{R2+RL+X2} \text{ and } \frac{A}{B} =$$

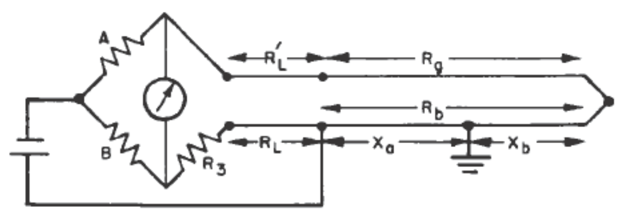
$$\frac{R'L + Rg + Rb}{R3RL}$$



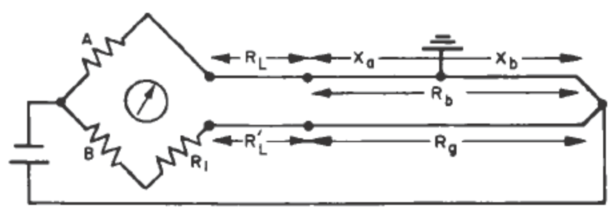
21B(a) "VARLEY 1" TEST



21B(b) "VARLEY 2" TEST



21B(c) "VARLEY 3" TEST



21B(d) MODIFIED "VARLEY 1" TEST

26.46.2

Figure 5-21B.—Simplified schematic diagrams for "Three Varley Tests".

From which may be obtained the working equation:

$$Xb = \frac{A}{A+B}(R2-R1) \quad Xa = \frac{A}{A+B}(R3-R2) \text{ and}$$

$$Rb = Xa+Xb = \frac{A}{A+B}(R3-R1)$$

R1 or Rb is resistance from test point to strap, (fig. 5-21B(a).
R2 or Xa is resistance from test point to trouble, (fig. 5-21B(b).
R3 or Rb+Xa is resistance of the complete loop from test point back to test point, (fig. 5-21B(c).

To determine the resistance to the fault to tenths of an ohm, the ratio A/B must be approximately 1/10. The ratio 1/9 and 1/4 are convenient in some models, because their working equations reduce, respectively, to the forms.

$$Xb = \frac{R2-R1}{10}, \quad Xa = \frac{R3-R2}{10} \quad \text{and } Rb = \frac{R3-R1}{10}$$

$$Xb = \frac{R2-R1}{5}, \quad Xa = \frac{R3-RL}{5} \quad \text{and} \quad = \frac{R3-R1}{5}$$

(fig. 5-21B(b) or (fig. 5-21B(c)

When the total resistance of the loop is more than about 1000 or 1100 ohms, it is impossible to balance the bridge when using the 1/10 or 1/9. It may then be necessary to use A/B = 1. Then, if the good wire is of lower resistance than the faulty wire the bridge cannot be balanced in the "Varley 1" test. The good and bad wires, with their leads, must be interchanged as in figure 5-21B(d), while making the "Varley 1" test only. The working equations under these conditions are:

$$Xb = \frac{R2+R1}{2}, \quad Xa = \frac{R3-R2}{2} \quad \text{and } Rb = \frac{R3-R1}{2}$$

(fig. 5-21B(d).

To avoid the need for interchanging the good and bad conductors in the "Varley 1" test, a small resistor may be connected between the test set and the good conductor. It is used during all three tests. Any reasonable value of resistance may be used which is large enough to make the resistance of the good conductor higher than that of the bad one. Its value need not be known since it is automatically eliminated by this method of test.

MURRAY LOOP TEST FOR LOCATING A GROUND

To use the Murray loop test for locating a ground, a good wire should be available (fig. 5-20) in addition to the grounded wire. Remove all equipment from both ends of the circuit and locate the fault as follows:

1. Adjust the galvanometer.
2. Position the test set controls as follows:
   a. GA switch to RVM
   b. RES-VAR-MUR switch to MUR
   c. MULTIPLY BY dial to M1000.
3. Make the following connections (figs. 5-20 and 5-21C).
   a. Connect the grounded wire to line binding post X_2.
   b. Connect the good wire to line binding post X_1.
   c. Connect the ground binding post to a good ground (cable sheath).
   d. Have a short placed across the far ends of the wires connected to line binding posts X_1 and X_2.
4. Balance the bridge and record the decade dial reading.

In this example the bridge is balanced with the Multiply BY dial set at M = 1000 and the total decade dial reading R = 600 ohms.

5. Use the direct computation method by solving for the distance d_a from the test point to the fault using the formula

$$d_a = \frac{RxL}{R+A}$$

a. In this example R = 600 L = total length of loop = 8 miles, and A = 1000 = Multiply BY dial reading. Substituting these values in above formula

$$d_a = \frac{600x8}{600+1000}$$

$$= \frac{4800}{1600} = 3 \text{ miles}$$

b. Use the resistance-distance method of computing the distance, d_a, from the test point to the fault as follows:

(1) Measure and record the loop resistance of the faulty circuit. In this example the loop resistance, r, is measured and found to be 370.4 ohms.

(2) Use the following formula to compute the resistance, X_a, (fig. 5-21C) from the test point to the fault.

$$X_a = \frac{Rxr}{R+A}$$

In this example R = 600 ohms, r = 370.4 ohms, and A = 1000. Substituting these values in the above formula and solving for X_a,

$$X_a = \frac{600x370.4}{600+1000}$$

$$= 138.9 \text{ ohms}$$

(3) Use the following formula to compute the distance, d_a, from the test point to the faults:

$$d_a = \frac{X_a}{1/2 \text{ resistance per loop mile}}$$

where the resistance per loop mile

$$= \frac{r}{\text{distance from test point to far end}}$$

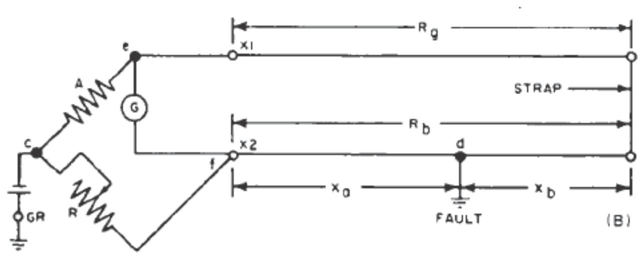
In this example r = 370.4 ohms total resistance of loop, and the distance from the test point to the far end is 4 miles. The resistance per loop mile $= \frac{370.4}{4} = 92.6$ ohms. Substituting these values in the above formula

$$d_a = \frac{138.9}{1/2x92.6}$$

$$= \frac{138.9}{46.3} = 3 \text{ miles}$$

(same as 5a above)

(4) To make a check test, reverse the wires connected to line binding posts X_1 and X_2



26.46.3

Figure 5-21C.—Regular Murray loop test for locating ground.

(fig. 5-20), balance the bridge, and use the following formula to determine the resistance, X_a, from the test point to the fault. (The computed resistance should be the same value as in 5b (2) above).

$$X_a = \frac{Axr}{A+R_2}$$

In this example R_2 = 1666 ohms, and r = 370.4 ohms. Substituting these values in the above formula and solving for X_a,

$$X_a = \frac{1000x370.4}{1000+1666}$$

$$= \frac{370,400}{2666}$$

$$= 138.9 \text{ ohms (same as in 5b (2) above).}$$

PREVENTIVE MAINTENANCE

The Wheatstone bridge like most meters should be inspected, cleaned, and tested at least once a year. However, if the test set is used often it may be necessary to inspect and clean it more often.

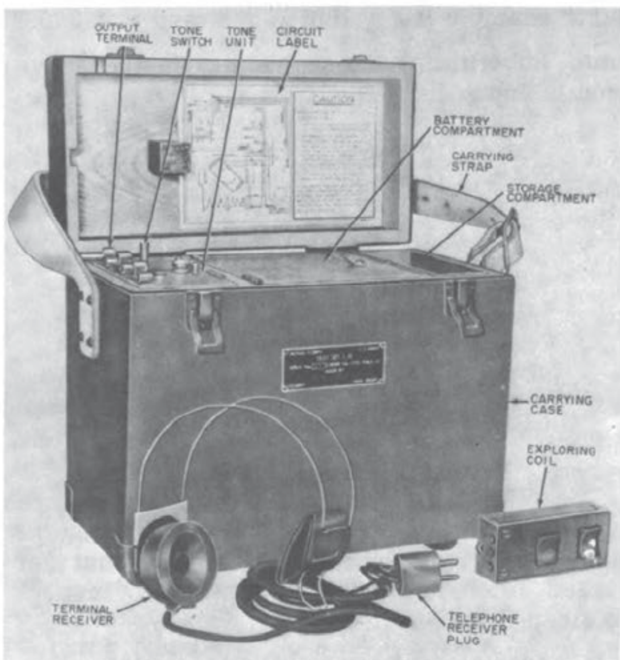
In order to perform preventive maintenance you should remove the screw in each corner of the panel and lift the panel from the carrying case to permit inspection and cleaning of the test set interior. Examine the contact surface of the five dial switches carefully. If dirty, wipe the surfaces clean with a cloth slightly moistened with cleaning compound and wipe dry. Apply a light coat of petroleum on the switch contact surfaces, and wipe the surfaces slightly with a clean cloth to leave a very thin film of lubricant on the surfaces. Replace the panel in the carrying case and check for normal operation.

WARNING: Cleaning compound is flammable and its fumes are toxic. Do not use near a flame and be sure adequate ventilation is provided.

CABLE REPAIRMAN'S TEST SET

The cable repairman's test set (fig. 5-22) is used to pinpoint the location of cable faults

after the approximate location of the fault has been obtained by the use of the Wheatstone bridge or some other method. The test set can be used to locate shorts, grounds, crosses, split pairs, wet spots, and similar troubles in a cable. IT CANNOT BE USED TO LOCATE OPEN CIRCUITS.



26.47
Figure 5-22.—Cable repairman's test set (I-51).

The test set includes a tone unit, an exploring coil equipped with three jacks, and a telephone receiver equipped with a cord and plug for connection to the exploring coil packs. The tone unit has a switch for selecting steady or interrupted tone and a set of terminals for connecting the tone unit to the faulty conductors. These units are housed in a carrying case which is provided with an adjustable carrying strap. The inside of the carrying case is divided into three compartments: one for the tone unit, one for the batteries, and one for storing the exploring coil and the receiver. In addition to the components supplied with the test set, it is necessary to have 4 (BA-23) batteries to furnish the required 6 volts, two alligator clips and approximately 10 feet of two-conductor cable required to assemble the test cord.

OPERATING PROCEDURES

Before you proceed to use the test set, you should first obtain information from the central office personnel on the type of cable fault, the resistance of the faulty conductors, and the approximate location of the fault.

LOCATION OF GROUNDS

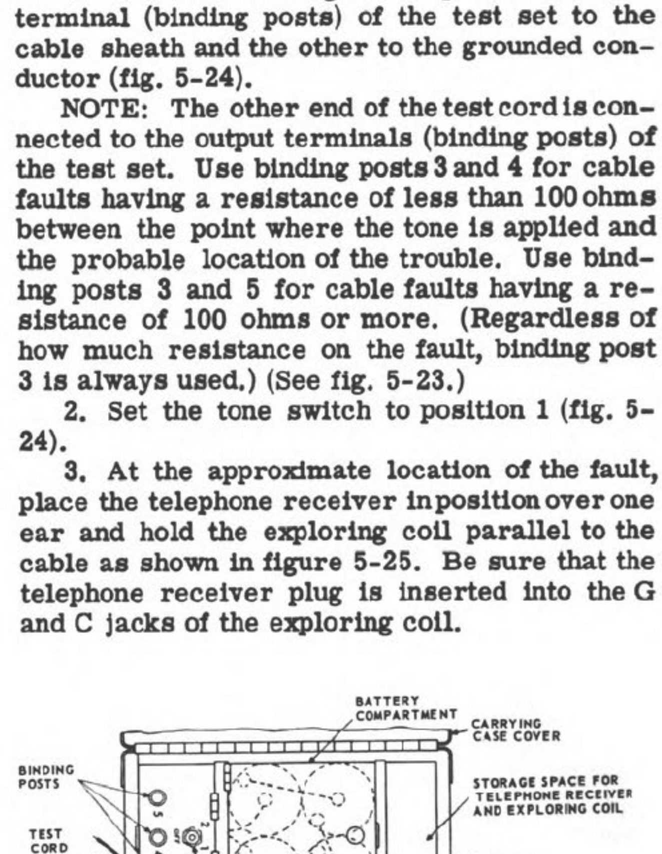
In locating grounds with the test set you will proceed in the following manner:

1. Connect the alligator clip of one output terminal (binding posts) of the test set to the cable sheath and the other to the grounded conductor (fig. 5-24).

NOTE: The other end of the test cord is connected to the output terminals (binding posts) of the test set. Use binding posts 3 and 4 for cable faults having a resistance of less than 100 ohms between the point where the tone is applied and the probable location of the trouble. Use binding posts 3 and 5 for cable faults having a resistance of 100 ohms or more. (Regardless of how much resistance on the fault, binding post 3 is always used.) (See fig. 5-23.)

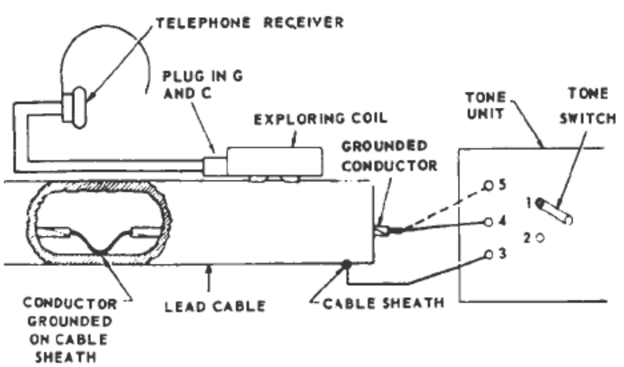
2. Set the tone switch to position 1 (fig. 5-24).

3. At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil parallel to the cable as shown in figure 5-25. Be sure that the telephone receiver plug is inserted into the G and C jacks of the exploring coil.



26.48
Figure 5-23.—Test set, top view with cover open.

4. While listening with the receiver, move the exploring coil along the cable toward the fault until the tone disappears or the volume of



26.49

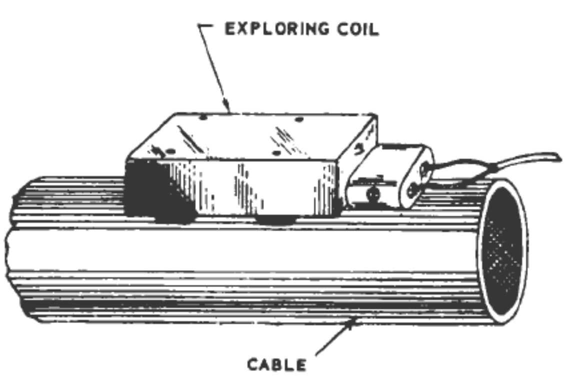
Figure 5-24.—Connections for locating grounds.

ıe tone is markedly decreased, which indicates ıe exact location of the fault.

NOTE: In high resistance faults, the tone ᵗill not disappear when the fault is passed be-ause of a carry-over effect of the line ca-acitance. In some cases, the change in volume s so slight that an absolute location of the fault s uncertain. In such cases, place a chalk mark t the approximate location, then transfer the est set to the other end of the cable, and re-eat the steps given above.

LOCATION OF SHORTS

A short circuit is caused by an insulation reakdown between the two conductors of a pair llowing the two wires to touch each other. A igh resistance short may occur if moisture



26.50

Figure 5-25.—Position of exploring coil for locating grounds, shorts, or split pairs.

enters the cable sheath and reduces the insulation resistance between the two wires of the pair to the point where the conductors cannot be used efficiently.

In locating shorts with the cable repairman's test set you will proceed in the following manner:

1. Connect the alligator clip from binding posts 3 and 4 or 5 as shown in figure 5-28. (See note under 1, Location of Grounds.)
2. Set the tone switch to position 2.
3. At the approximate location of the fault, place the telephone receiver plug in position over one ear and hold the exploring coil parallel to the cable as shown in figure 5-25. Be sure that the telephone receiver plug is inserted in S and C jacks of the exploring coil.
4. While listening with the receiver, move the exploring coil along the cable toward the fault. The tone will decrease and increase in volume as the coil is moved along the cable. This is called the short-circuited effect. When the coil is moved over the fault, the tone either will decrease considerably in volume or disappear entirely.

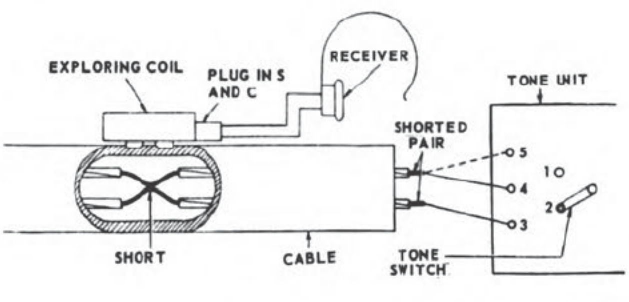
NOTE: If uncertain of the exact location, then transfer the test set to the other end of the cable and repeat the steps given above. (Connections for locating shorts shown in fig. 5-26.)

LOCATION OF CROSSES

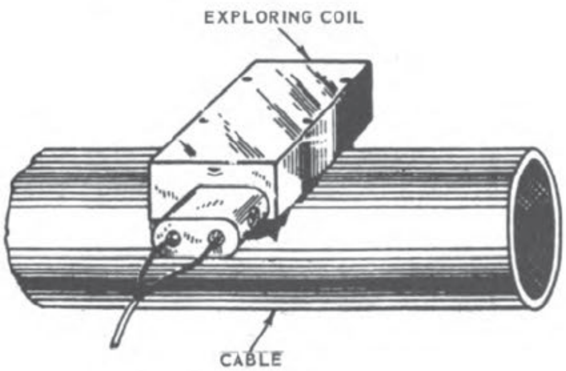
A cross is essentially the same as a short except that the contact is between conductors from two different pairs.

To locate crossed wires you will proceed in the following manner:

1. Connect the alligator clips of the output terminal to the crossed conductors. (See note under 1, Location of Grounds.)
2. Set the tone switch to position 1.
3. At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil at a right angle to the cable as shown in figure 5-27. Be sure that the telephone receiver plug is inserted into the S and C jacks of the exploring coil.
4. While listening with the receiver, move the exploring coil along the cable toward the fault until the tone fades out or is reduced considerably in volume. The steady volume tone heard while tracing crossed wires is known as the crossed-wires effect. (Connections for locating crossed wires is shown in fig. 5-28.)

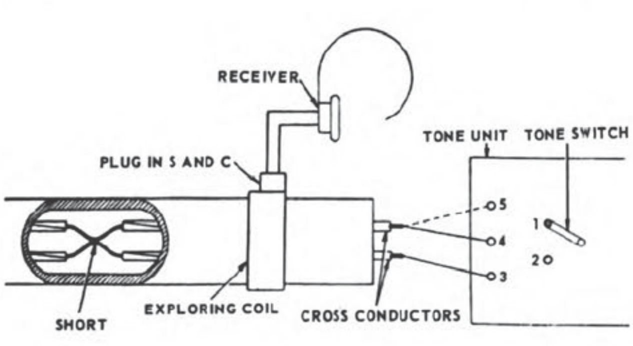


26.51
Figure 5-26.—Connection for locating shorts.



26.52
Figure 5-27.—Position of exploring coil for locating crosses and wet spots.

NOTE: If uncertain of the exact location of the fault, place a chalk mark at the approximate location, then transfer the test set to the other end of the cable and repeat the steps given above.



26.53
Figure 5-28.—Connections for locating crossed wires.

LOCATION OF SPLIT PAIRS

A split pair is caused by splicing error in which one wire of a pair is connected to one wire of another pair.

In locating a split pair you will proceed in the following manner:

1. Strap the four wires of the two split pairs together at the far end of the cable.
2. Connect the alligator clips of the output terminals to one of the split pairs. (See NOTE under 1, Location of Grounds.)
3. Set the tone switch to position 2.
4. At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil parallel to the cable as shown in figure 5-25.
5. While listening with the receiver, move the exploring coil along the cable toward the fault. The tone will increase and decrease in volume (short-circuit effect) up to the location of the fault and, thereafter, will be steady in volume (crossed-wires effect). (Connection for locating split pairs is shown in fig. 5-29.)
6. To ensure accurate location of the fault, mark the cable at the location found in 5 above, and then use the alternative method of locating split pairs as a check.

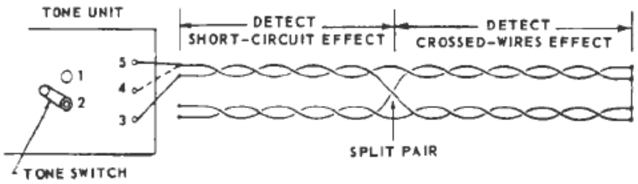
ALTERNATIVE METHOD OF LOCATING SPLIT PAIRS

1. Connect the alligator clips of the output terminals of the test set to one wire of one of the split (strapped at the far end of the cable) and to one wire of the other pair as shown in figure 5-30.
2. Set the tone switch to position 2.
3. While listening with the receiver, move the exploring coil along the cable toward the fault. The tone will be steady in volume (crossed-wire effect) until the fault is reached; thereafter the tone will increase and decrease in volume (short-circuit effect).

NOTE: It is possible to connect the test set in such a manner that the short-circuit effect will not be detected. If this happens, reconnect one of the test leads to the other wire of the pair to which it is connected. The short-circuit effect now should be heard as described above.

LOCATION OF WET SPOTS

Normally a wet spot in a cable is caused by an opening in the cable sheath. In aerial cables,

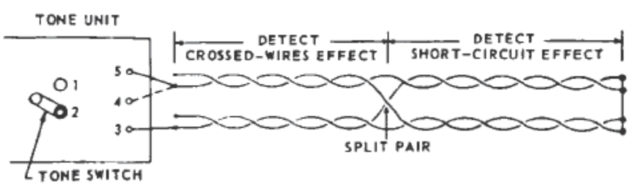


26.54
Figure 5-29.—Connections for locating split pairs.

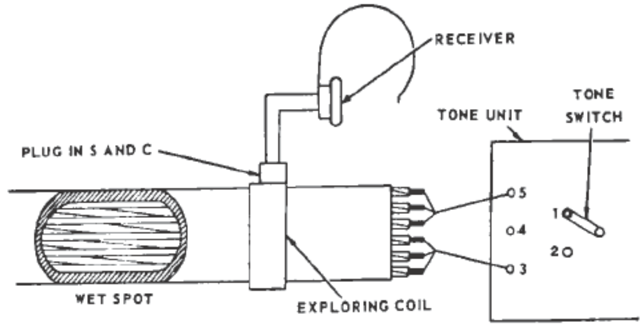
this opening can be caused by squirrels chewing on the cable sheath or by tree limbs, cable rings, or cable lashing wire rubbing against the sheath. In underground cables, an opening in the sheath normally is caused by soil erosion or electrolysis. When an opening appears in the sheath, moisture eventually enters the cable and forms a combination of grounds, short circuits, and crosses.

In locating wet spots with the test set, you will proceed in the following manner:

1. Connect the alligator clips of the output terminals to each group of strapped wires (fig. 5-31).
2. Set the tone switch to position 1.
3. At the approximate location of the fault place the telephone receiver in position over one ear and hold the exploring coil at right angles to the cable as shown in figure 5-27. Be sure that the telephone receiver plug is inserted into the S and C jacks of the exploring coil.
4. While listening with the receiver, move the exploring coil along the cable toward the fault. A steady tone will be heard up to the location of the fault and, thereafter, the tone either will decrease considerably in volume or disappear entirely.
5. To ensure accurate location of the fault, mark the cable at the location found in 4 above, and use the alternative method of locating wet spots as a check.



26.55
Figure 5-30.—Alternative connections for locating split pairs.



26.56
Figure 5-31.—Connections for locating wet spots.

ALTERNATIVE METHOD FOR LOCATING WET SPOTS

1. Strap together one group of wires which have a low resistance to ground.
2. Connect the alligator clip of one output terminal of the test set to the cable sheath and the other to the strapped group of wires (1 above).
3. Leave the tone switch set to position 1.
4. At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil parallel to the cable as shown in figure 5-25. Be sure that the telephone receiver plug is inserted into the G and C jacks of the exploring coil.
5. While listening with the receiver, move the exploring coil along the cable toward the fault until the tone disappears or the volume of the tone is markedly decreased, which indicates the exact location of the fault.

LOCATION OF BURIED CABLE

It sometimes becomes necessary to trace the path of a buried cable, the location of which is not known. Also, when there is trouble in a buried cable, much excavation may be avoided if the exact location of the cable can be determined. Only the tracing methods directly applicable to buried cable are discussed in this section.

In conjunction with the cable repairman's test set I-51, the following items of equipment are required for tracing buried cable:

Amplifier----BC-1388
Coil---------24 or 26 inch diameter exploring induction coil

Receivers ---Two No. 716-D receivers equipped with a WECo R2CF cord and a WECo 11A headband
Rods --------Two ground rods, GP-26

The exploring coil is not available as a standard item, but can be constructed locally as follows:

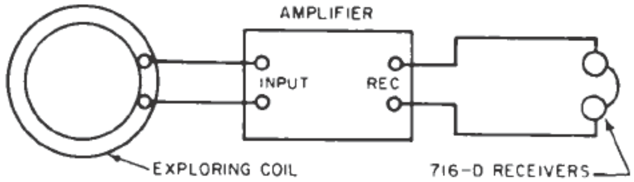
Wind approximately 300 turns of No. 24-gage double cotton-covered copper wire on a light circular frame with a diameter of 24 or 26 inches to make the coil. Then bring the two ends of the windings about 1/2 inch apart from the side of the coil. Wrap a layer of rubber tape and then a layer of friction tape in the reverse direction over the wound wire, bringing the ends of the wire out of the coil between the layer of the tapes. Terminate the ends of the winding by soldering them to binding posts mounted in a small insulating strip. A piece of hard rubber 3/16 inch by 3/4 inch by 2 1/2 inches will serve satisfactorily as the strip. Apply two coats of asphalt paint to the entire coil. Then fasten the terminal strip to the inside of the completed coil.

In an emergency any fine-gage insulated wire wound into a coil about 2 feet in diameter can be used in place of the coil described above.

Under some conditions, the pickup of the exploring coil will be sufficient to give a suitable signal when connected directly to the No. 716-D receivers. If the signal is not strong enough to permit tracing, an amplifier, such as the BC-1388, is connected to the listening circuit. Figure 5-32 shows a schematic view of the exploring coil.

Stray Current Method of Tracing Conductor

In locating and tracing the path of a buried cable or a conductor which is not readily accessible, it is generally advisable first to attempt to make a location by the stray current method with the coil held in a horizontal position. Walk across the approximate path of the conductor to determine whether there is sufficient stray current flowing to give an audible signal or tone in the receivers. If there is, the tone volume will rise gradually to a maximum as the conductor is approached, suddenly fall to a low value when the coil is directly over the conductor, rise again to previous maximum as the conductor is passed, and then decrease slowly. If the exploring is done in the proximity of a power line, most of the tone heard may be the result of induction from the line.



26.57

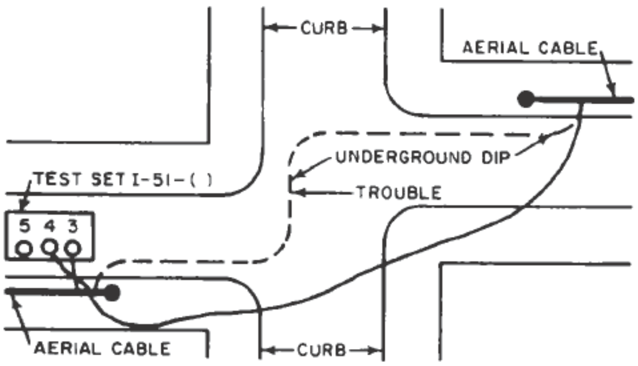
Figure 5-32.—Exploring for tracing buried cable.

Tracing Conductor by Use of Test Set I-51

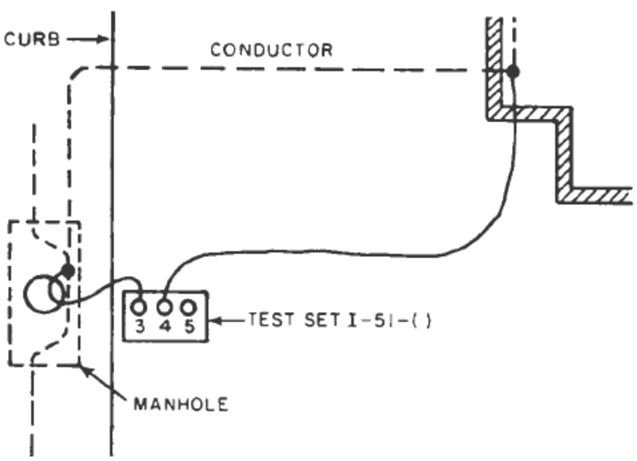
If there is too much disturbance from the power line, or if the tone volume is inadequate, the stray current method will not be effective. Under such conditions the locating and tracing of a cable can generally be facilitated by using Test Set I-51 as a source of tracing current. The test set is placed as far as possible from the conductor at the point of tracing. The set may then be connected in any one of three ways, depending on the distance to be covered and the accessibility of the conductor to be located. Regardless of the method of construction, intermittent tone should be used in the set.

When the conductor to be traced is relatively short and is accessible at two points, as shown in figures 5-33 and 5-34 (one on each side of the area in question), it is advisable to connect the set directly. The connection is made with insulated wires which are attached to terminals 3 and 5 of the set, and are placed on the ground in such a way that they will not parallel the conductor in the area where the location is made. Intermittent tone should be used.

When the conductor to be traced is accessible at one point and the approximate location is known at another point, the tracing current can be applied as illustrated in figure 5-35. Install the ground rod 5 to 20 feet from the cable. Connect the set to the conductor and rod as described above, except that a number 3 bridging connector may be used to attach the lead to the rod.

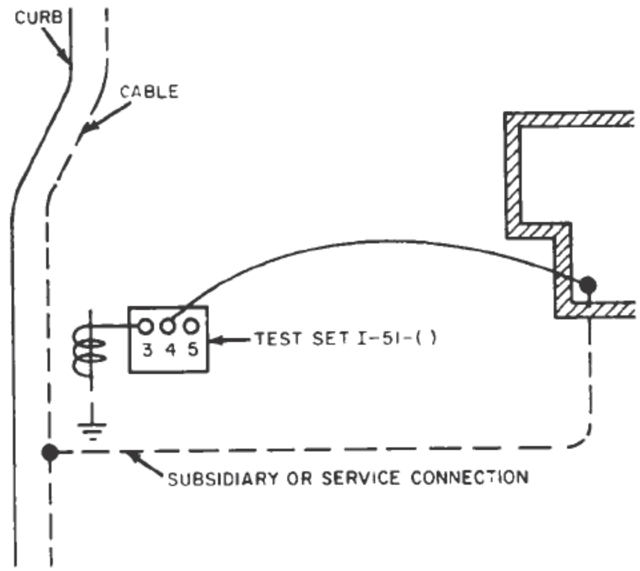


26.58
Figure 5-33.—Tracing buried cable conductor with test set I-51, underground dip.



26.59
Figure 5-34.—Tracing cable conductor in underground subsidiary with test set I-51.

If the conductor to be traced is not accessible and the approximate location is known, install one ground rod close to the conductor (5 to 20 feet), and another ground about 50 feet from the first ground rod and in a line approximately at right angles to the conductor (fig. 5-36). If the approximate location of the conductor is not known, the separation between the rods should be about 100 feet. If a power line is in the vicinity of the conductor, place the rods on the power-line side of the conductor. Drive the rods approximately 2 1/2 feet into the earth; but where the soil is loosely packed or contains many small stones, drive the rods deeper, or move them to another location where the soil conditions are more

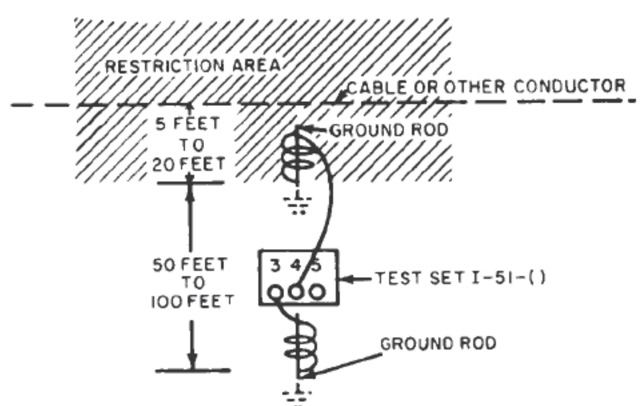


26.60
Figure 5-35.—Tracing accessible conductor with test set I-51, and one ground rod.

favorable. If the separation between rods is not over 50 feet, make location tests at a point not less than 100 feet from the rods. Within this area a strong tone will be heard, but the location will not be reliable. Where the separation is more than 50 feet, the restricted area extends about 200 feet from the conductors.

Locating Conductors

To locate conductors stand at a point that is believed to be near the cable or conductor



26.61
Figure 5-36.—Tracing inaccessible conductor with test I-51 and two ground rods.

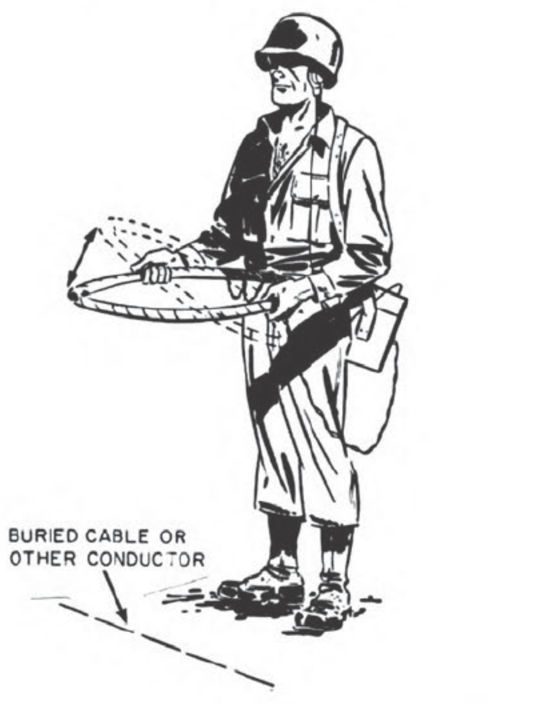
(on the side away from any power line, if there is one near by). Hold the exploring coil in a horizontal position and rock it slowly around a horizontal axis which is considered parallel to the conductor, as shown in figure 5-37.

When maximum tone is heard in the receivers, the plane of the coil is at right angles to this position. A further check on the location can be made by holding the exploring coil in a vertical position and then rotating the coil around its vertical axis. When the tone in the receivers is at a minimum, the plane of the coil is perpendicular to the conductor. When the tone is at a maximum, the plane of the coil is parallel to the conductor. If no definite maximum or minimum tone position can be found, the tests are repeated at other points in the general vicinity.

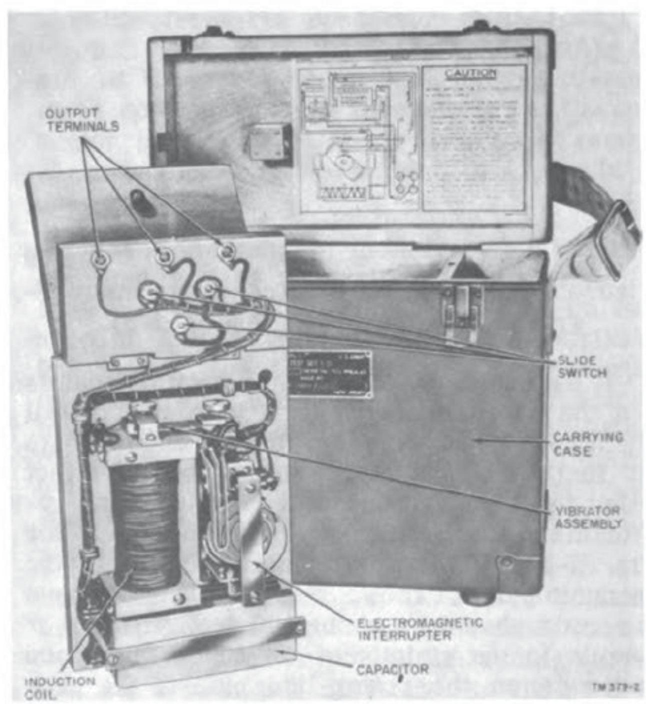
After the general location of the conductor has been determined, the following procedure will be followed to find the exact location. Starting at the point where the approximate locations were made and with the coil in a horizontal position, walk toward the conductor. The tone volume will rise gradually to a maximum as the conductor is approached, suddenly fall to a low value when the coil is directly over the conductor, rise again to the previous maximum as the conductor is passed, and then decrease slowly. If a check test is desired, hold the coil in a vertical position, with the plane of the coil parallel to the conductor, and again walk across the conductor. The tone volume will rise as the conductor is approached, reach a maximum directly over the conductor, and then decrease as the conductor is passed.

PREVENTIVE MAINTENANCE

The most important preventive maintenance techniques to be applied to the cable repairman's test set I-51 are the visual inspection and cleaning. To perform the maintenance operations listed below, it will be necessary to remove the tone unit from the carrying case (fig. 5-38). Lift the battery case cover and the cover on which the tone switch is mounted and, using them as a handle, lift the tone unit straight up and out of the carrying case.



26.62
Figure 5-37.—Getting general location of buried cable.



26.63
Figure 5-38.—Test set I-51, tone unit removed from carrying case.

Inspection

Perform the inspections and checks listed below. Repair all loose or broken connections discovered.

CAUTION: Tighten screws, bolts and nuts carefully.

Fittings tightened beyond the pressure for which they are designed will be damaged or broken.

1. Check for completeness and general condition of the test set.
2. Check and tighten mounting screws on all components.
3. Inspect for loose or broken electrical connections; loose or broken parts; cut, frayed, or bare wires, cable, or webbing.
4. Check for accumulation of dust and dirt.
5. Inspect batteries for corrosion.
6. Check battery voltage.
7. Check for normal operation.

Cleaning

1. Clean the carrying case.
2. Clean the tone unit with a camel's-hair brush.
3. Thoroughly clean and polish the insulated areas between the line terminals on the set and between the receiver jacks on the exploring coil. Remove all traces of lint after cleaning.
4. Remove corrosion from battery terminals with a clean cloth.
5. Clean the receiver unit.

WIRE CHIEF'S TEST DESK

The wire chief's test desk is the major center for fault location and trouble tests in a telephone central office. Although other test sets are used in the telephone plant, most of the basic maintenance testing is done at the test desk. The wire chief and other maintenance personnel in the plant should become thoroughly familiar with the test desk and its associated equipment and circuitry. The information on the wire chief's test desk, which is presented in this chapter, is typical and may not be precisely applicable to all test desk installations. There is a manual of operation and maintenance with each installation.

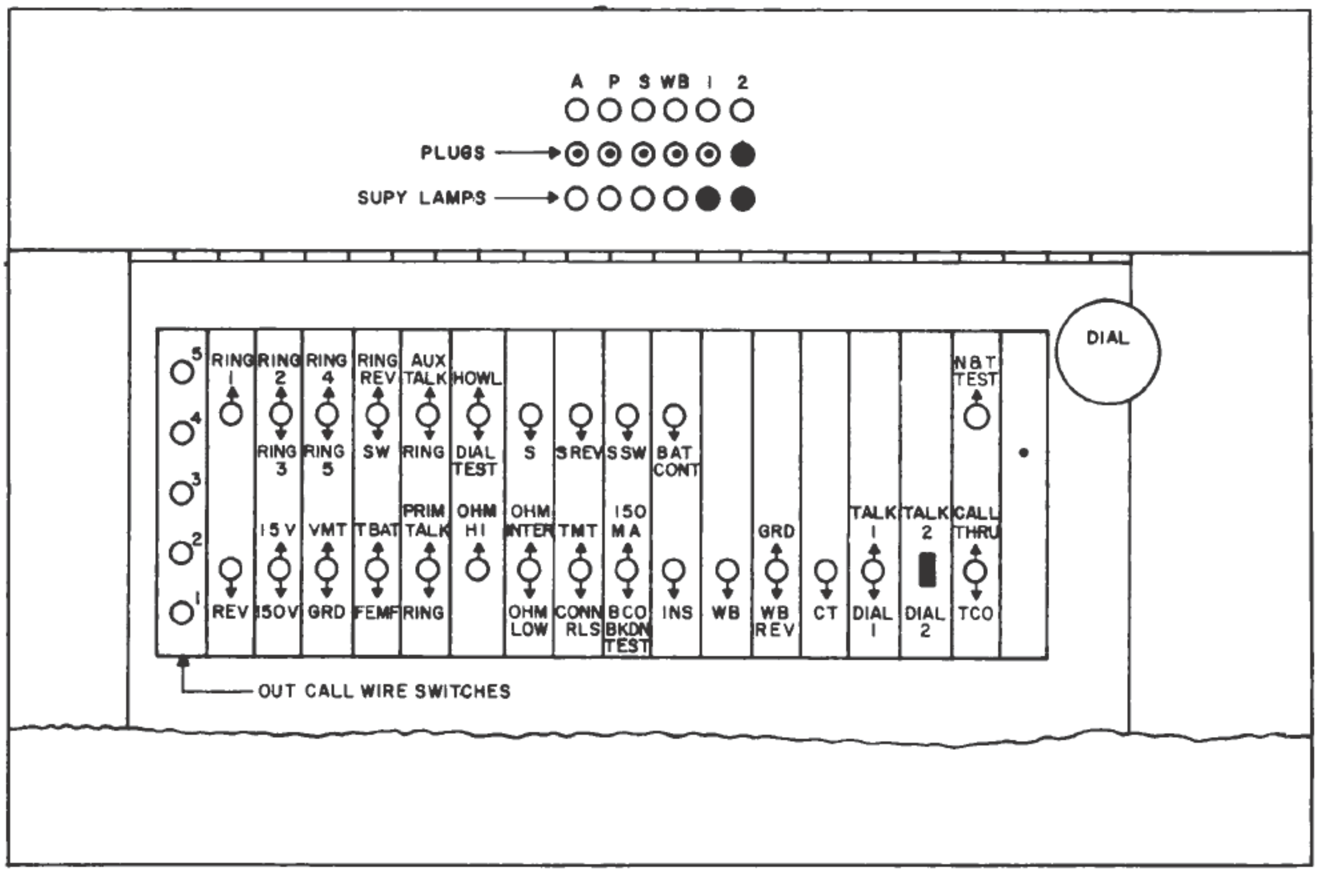
The test desk is normally used for checking troubles on the station lines. Usual troubles encountered consist of open circuits, short circuits, insulation leakage, crosses, wiring errors, or faulty station equipment.

OPERATION OF THE DESK SET

The operation of the test desk consist of many steps for each of the various tests which may be conducted. For our purpose, we will explain three of the tests to give you an idea of how the desk works. The illustration of the switch shelf (fig. 5-39) will assist you in following these steps. The typical desk set contains various meters, a Wheatstone bridge, test cords, other equipment, and extensive circuitry which tie the test desk in with the other central office equipment.

Open Circuit Test

With the volt-ohm-milliammeter located on the desk set, you can test the line for open circuits with the primary test cord. As soon as the connection is established with the line under test A, loop test may be made with a 15-volt or a 150-volt test battery in series with the meter circuit. Operate the 15-volt to 150-volt lever key (third lower left key in fig. 5-39, for example) in the 150-volt position for the loop test with the 150-volt battery. When the key is set in the 150-volt position, a direct ground is placed on the tip (+) side of the test circuit, and the negative battery lead is connected in series with the meter circuit to ring (-) side of the test circuit (fig. 5-40). When the test circuit is thus connected to a closed loop circuit, current through the loop will cause the meter to indicate on its 0- to 150-volt scale. No indication will occur on vacant lines or lines with an open. Meter indications on this test can give you answers to other things that may be on the line you are testing. A closed loop will cause a steady indication on the meter. A steady indication may also be caused by short circuits or a ground on the ring (-) side of the line. The value of the voltage indicated on the meter is a relative indication of the resistance of the circuit. The voltage drop indicated by the meter should be in proportion to the resistance of the line you are testing. A reading equal to the test battery voltage indicates a short circuit. A reading in excess of test battery voltage indicates the presence of foreign potential on the line.



26.190

Figure 5-39.—Test desk switch shelf and plug shelf equipment.

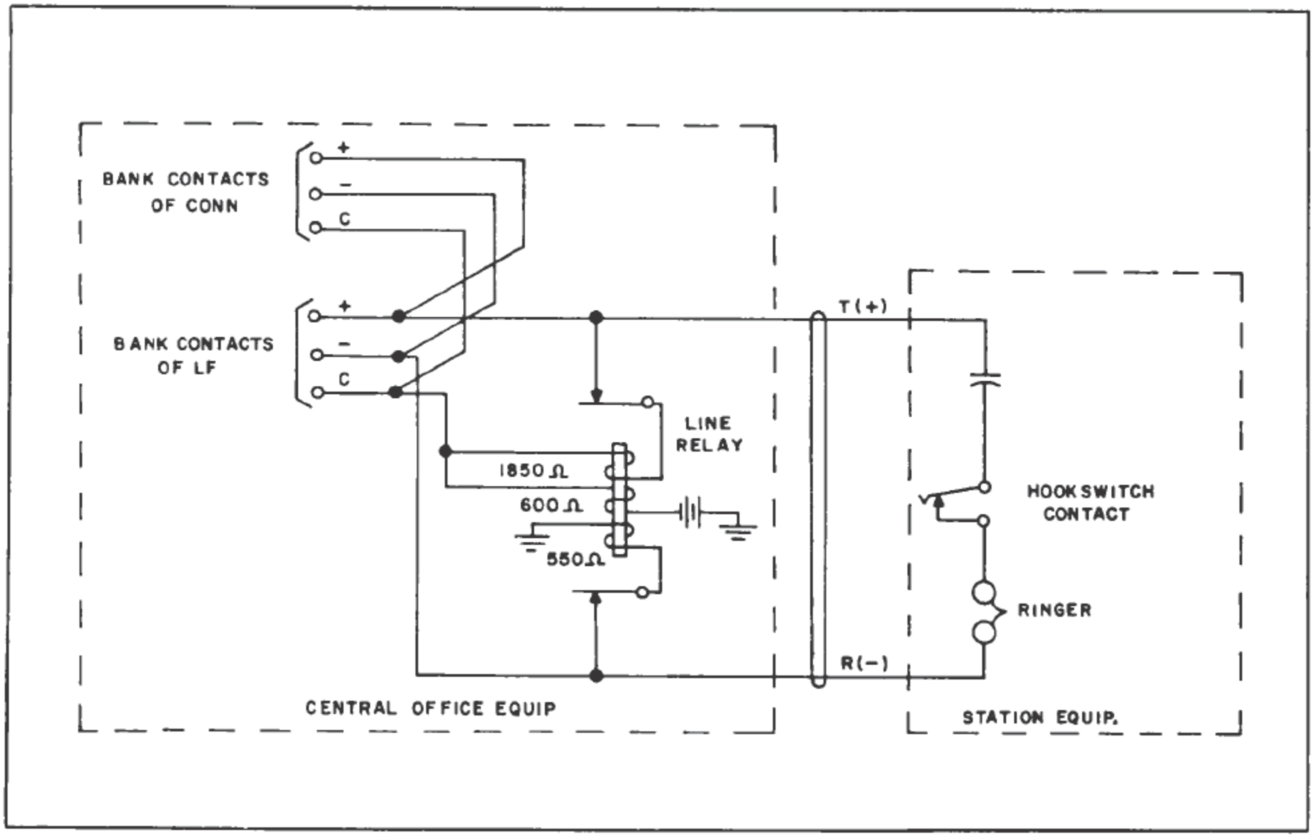
Test for Ground on Line

When a loop test indicates that one or both lines may be grounded or that further tests are required, test for grounds on the tip (+) and on the ring (-) sides of the line. Operate the 15-volt to 150-volt lever to the 150-volt position and operate the VMT-GRD key (fourth lower left in fig. 5-39) to the GRD position. This opens the circuit to the T (+) test lead (see fig. 5-40) and grounds the positive side of the test battery. A ground on the ring (-) side of the line will complete a circuit through the meter, thus causing a voltage indication proportional to the resistance of the ground.

To test for ground on the tip (+) side of the line, operate the 15-volt to 150-volt lever key to the 150-volt position, and operate the VMT-GRD key to the GRD position as before. Then operate the REV lever key (second lower left in fig. 5-39). This reverses the connection to the T and R leads of the primary test circuit, so that a ground on the tip (+) side of the line will cause a voltage indication on the meter.

Insulation Breakdown Test

The insulation breakdown test is made by connecting, across the line being tested, a 200-volt test battery in series with the milliammeter, two current-limiting resistance lamps, and the relays connected to a rotary switch in the howler. The auxiliary test cord may be used by operating the RING REV-SW key (fifth left upper in fig. 5-39) to the SW position. For the breakdown test on the tip (+) side of the line operate the INS BK DN test lever. This connects ground to the ring (-) side of the line and starts the howler. As the howler operates, the positive side of the 200-volt test battery is alternately closed to the



26.191

Figure 5-40.—Normal dial station line circuit.

tip side of the line and is then opened (the negative side of the 200-volt battery is grounded).

The duration of the howler operating cycle is 12 1/2 seconds. The testman may observe the milliammeter for current flow. A reading greater than 20 milliamperes indicates trouble on the line. To test the breakdown on the ring side of the line operate the REV lever key. This reverses the test circuit connections to the test cord. The procedure for tests on the ring side is then exactly the same as for the tip side of the line.

CONNECTING THE WHEATSTONE BRIDGE

To tie the Wheatstone bridge in with the test desk, connect the bridge to a line through the primary test cord and one of the test trunks. Operate the WB lever key (sixth right lower in fig. 5-39). This connects the line through the test circuit to the Wheatstone bridge. Then operate the controls of the Wheatstone bridge referring to the instructions supplied with the bridge by the manufacturer.

CHAPTER 6

POWER GENERATORS

As a Construction Electrician First Class or a Chief Construction Electrician, you may have the responsibility of supervising the installation, operation, maintenance, and repair of advanced-base type generating equipment. This equipment is portable and ranges in size from 1.5-kw to 600-kw. In time of war or national emergency portable generating equipment will normally be used at temporary overseas bases. Even in peacetime, portable equipment may be used at remote bases.

At large, more permanent activities, you may have duties associated with the installation of large electrical power systems. Recently the Seabees constructed an atomic power plant in Antarctica. The plant installed at this location has an output of 2000-kw at 4160-volts, with the necessary switchgear and controls for distribution of power.

GENERATOR SELECTION

When an overseas base is first established, electric power is needed in a hurry; you will not have time to set up a centrally located generating station. Instead, you will spot a portable plant at each important location requiring power. Table 6-1 lists some of the standard alternating current generators available. One standard generator not listed in the table is the 600-kw generator which will be described in detail later in this chapter. These standard generators are capable of meeting the power requirements of advanced bases.

The 1.5-kw output generator delivers 120 volts single phase at a frequency of 60 cycles. It is a very versatile and widely used small generator because its output is adequate for the communications and lighting requirements for use in the field. Figure 6-1 shows a typical 1.5-kw generator mounted on a base with handles to make it transportable by two men. The simplicity of operation is evidenced by a single control, consisting of a field rheostat or voltage-regulator control to permit adjustment of the voltage and frequency of the output. A typical 10- and a typical 60-kw generator are illustrated in figures 6-2 and 6-3.

The electrical loads to be supplied, power, voltage, phase, and frequency requirements govern the selection of generating equipment. Probable load deviation, probable life of the installation, availability of fuels, and availability of skilled personnel are other important factors.

Electrical plants at advanced bases serve a varied load of lighting, heating, and power equipment, most of which demand power day and night. The annual load factor (the ratio of average power to peak power) of a well operated active base should be 50 percent or more with a power factor (explained later in the chapter) of 80 percent or higher. If the load is more than a few hundred feet from the power source, a high voltage distribution system is required.

If several generators are to serve primary distribution systems, they should generate the same voltage to avoid need for voltage transformation. The number of phases required by the load may differ from that of the generator. As loads can usually be divided and balanced between phases, most generators of appreciable size are wound for three-phase operation.

POWER AND VOLTAGE REQUIREMENTS

The power and voltage requirements of the load will normally determine the size of the generator to be used. For example, electrical equipment rated at 120 volts, single phase with a combined power load of less that 1500 watts can be adequately handled by a gasoline or diesel-driven power plant with a 120-volt,

Table 6-1.—Family of Engine-Generators

	Alternating current					
Frequency	60-cycles					
Voltage	120		120/208		120/208 240/416	
Phase	1		1 & 3		3	
Wires	2		4*		4	
Fuel	G	D	G	D	G	D
KW Rating						
1.5	x					
3			x			
5			x			
10			x			
15					x†	x†
30					x†	x†
45						x†
60					x	x†
75						x†
100						x†
150						x†

G—Gasoline driven. D—Diesel driven.
† —These generators to produce either 50- or 60-cycle current.
* —Panel connections permit, at rated KW output: 120/208v 3-phase 4-wire, 120v 3-phase 3-wire, 120v single phase 2-wire, 120/240v single phase 3-wire.

2-wire output rated at 1.5 kw. If the power demand of the equipment is greater than 1.5 kw, but does not exceed 4.5 kw, a generator rated at 5 kw, 120 volts, with a 2-wire output can be used. However, if motors are included as part of the load, then the generator capacity must be increased above that which would normally be used. When starting a large motor, the reduction in terminal voltage, along with the frequency surges occurring during the motor accelerating period may affect the performance of electronic systems and other electrical equipment supplied from the same generator. Furthermore, other motors already running may stall because of this low transient terminal voltage. When a large motor is being started, part or all of the existing load should be removed to avoid such conditions. These smaller loads may be put back on the generator after the large motor has come up to speed. If a single-phase load contains equipment rated at both 115 and 230 volts, a 3-, 5-, or 10-kw diesel- or gasoline-driven generator with a 120/240-volt, single-phase, 3-wire output can be used, depending on the load requirements.

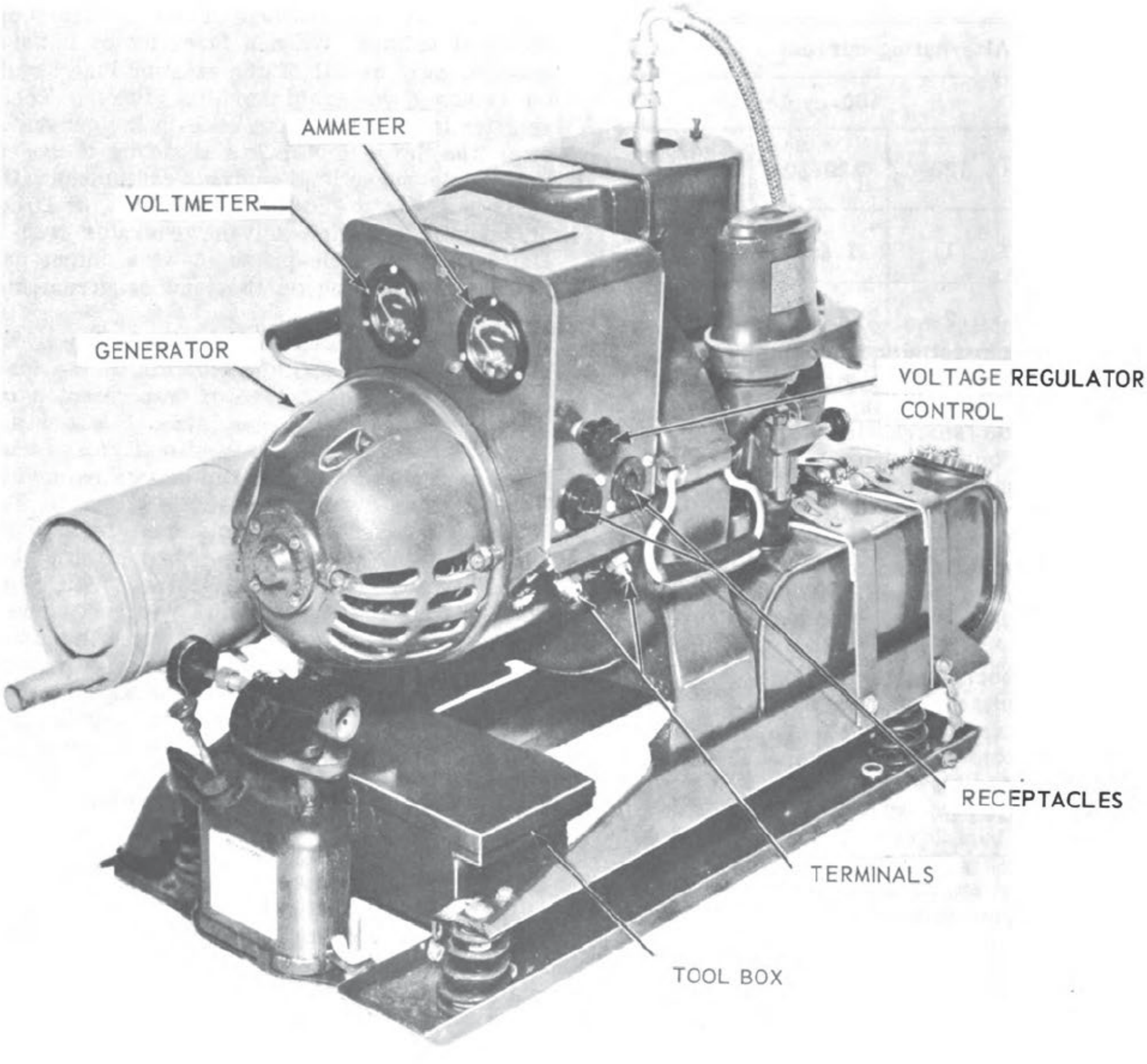
The selection of voltage is affected by the size, character, and distribution of the load; length, capacity, and type of transmission and distribution circuits; and size, location and connection of generators. Practically all general purpose lighting in the United States and at United States overseas bases is 120 volts. The lighting voltage may be obtained from a 3-wire, 120/240-volt, single-phase circuit or a 120/208-volt, three-phase, 4-wire circuit. Some small motors can be supplied by direct current or single phase alternating current at nominally 120 volts. Large three-phase a-c motors, above 5 horsepower, will generally operate satisfactorily at any voltage between 200 and 240. The general use of combined light and power circuits increases the use of 240 or 208 volts for general power application.

COMPUTING THE LOAD

As mentioned earlier in this chapter there are various factors that must be taken into consideration in the selection of the required generating equipment. The following technical data will help you in computing the load.

Demand Factor

Demand factor is the ratio of the maximum LOAD DEMAND to the total connected load. CONNECTED LOAD is the sum of the rated capacities of all electrical appliances, lights, heaters, motors, and so on. The ACTUAL DEMAND is generally much less than the connected load because different pieces of apparatus are used at different times or because



26.64

Figure 6-1.—Typical 1.5-kw, 120-volt, 60-cycle, portable generator set.

the peak loads of these various pieces are not usually simultaneous. An exception occurs where all utilization apparatus is of the same general type and used at the same time to full capacity such as shop or street lighting. For example, a repair shop may have a 31.4-kw maximum demand by actual measurement. The total connected load may be as follows:

Thirty 60-watt lamps	1.8-kw
Twenty 100-watt lamps	2.0-kw
Motors, total connected	30.0-kw
Welding equipment	20.0-kw
Heating apparatus	9.0-kw
Total connected load	62.8-kw

$$\text{Demand factor} = \frac{\text{Maximum demand}}{\text{total connected load}} = \frac{31.4}{62.8}$$

0.5 or 50%

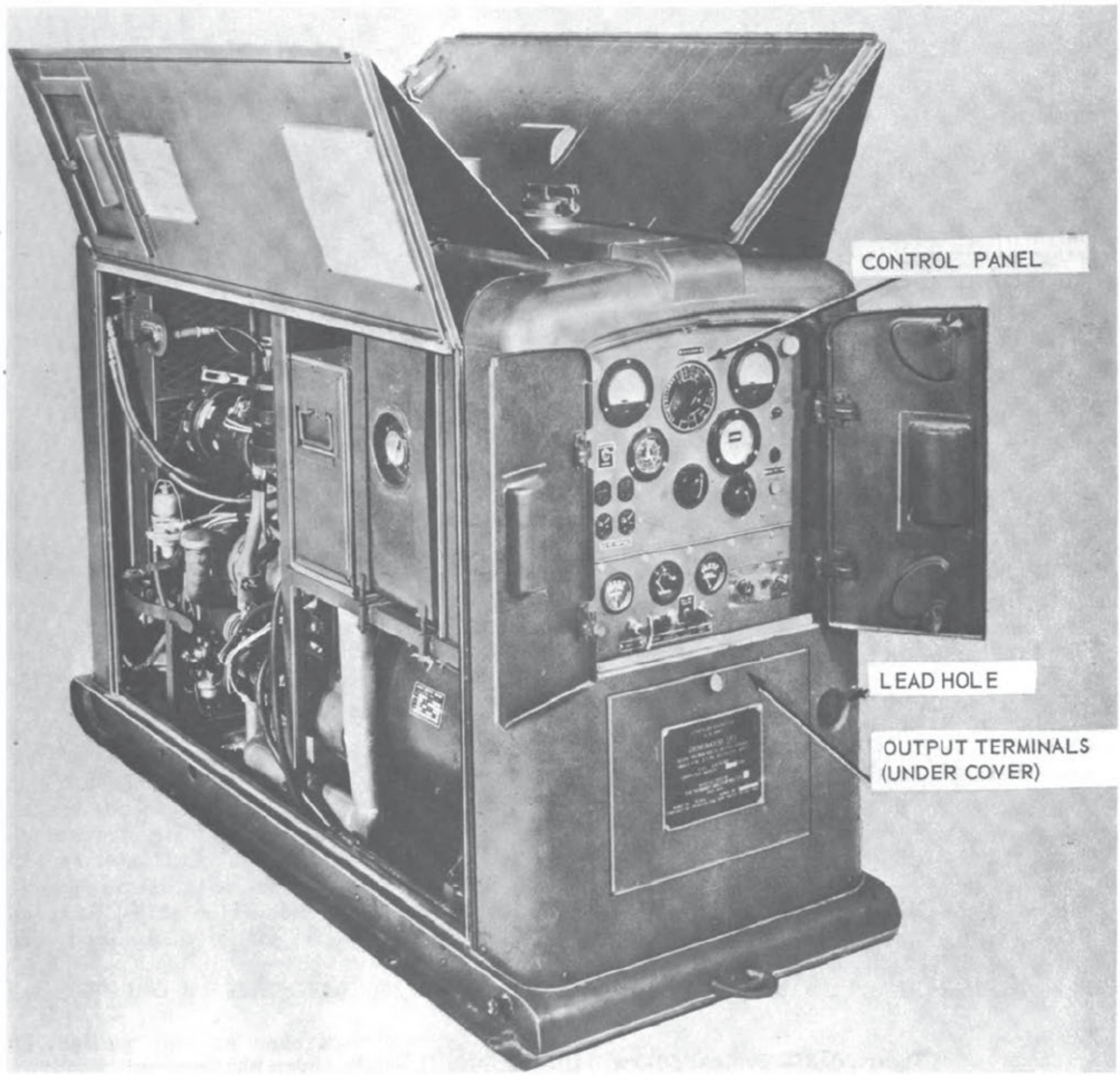


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Figure 6-2.—Typical 10-kw, 120/208-volt, three phase, 4-wire, 60-cycle portable generator set.

Diversity Factor

The diversity factor is the ratio of the sum of the maximum power demand of component parts of any system to the maximum demand of that system as a whole measured at the point of supply. For example, a generator may serve three different demand locations, each with a maximum demand of 30 kw, the maximum demand on the generator may be only 60 kw instead of 90 kw because the maximum demand of three locations do not occur simultaneously. This is illustrated in figure 6-4. Because the three loads A, B, and C

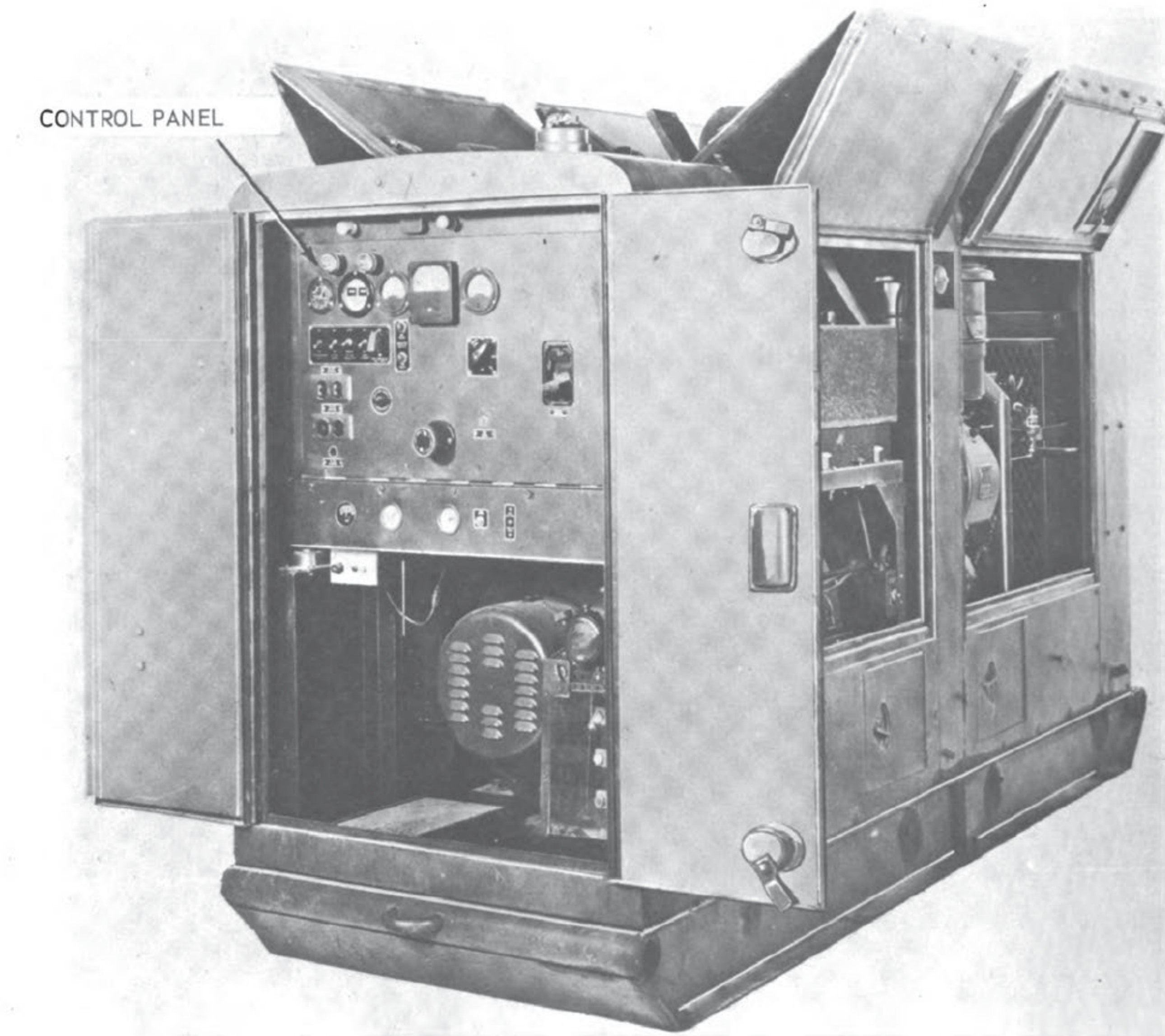

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Figure 6-3.—Typical 60-kw, 120/208/240/416-volt, three phase, 4-wire, 60-cycle diesel driven generator set.

vary in time, the generator at any one time need supply only the actual demand of the three loads, which in this case is 60. The diversity factor is:

$$\frac{90}{60} = 1.50$$

Power Factor

For a-c systems the power factor is defined as the ratio of the true power (watts) to the apparent power (volt-amps). True power is the actual power used in the load and may be measured by a wattmeter. The apparent power is the product of the voltage impressed on the load and the current flowing through the load.

Application of Demand and Diversity Factor

Application of demand and diversity factor in planning electrical facilities is a major

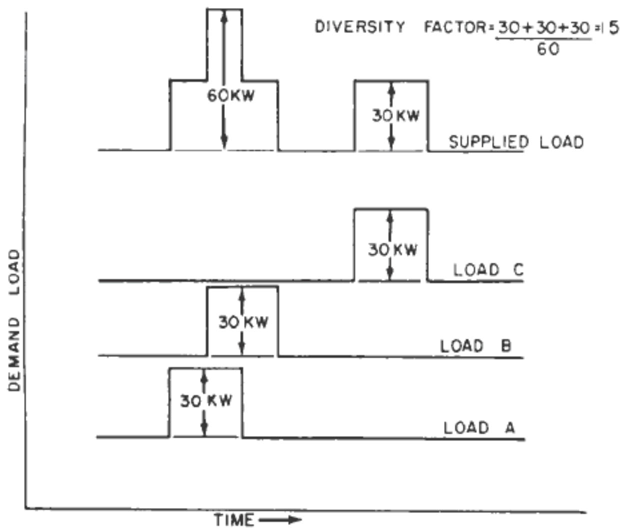

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Figure 6-4.—Diversity factor.

consideration when requisitioning electrical generators. Knowing the demand factors for various types of buildings, equipment and installations is also beneficial when rearranging existing facilities because increased serving capacity is often not required, even though the connected load is greatly increased. Diversity factors of important loads must be considered when they contribute to the peak load. Some loads are at maximum demand at the same time as the peak load on the system; other loads occur at a time different from the peak and add little to the required capacity of the generator. For example, an electrified mess hall adds only about 25 percent of its actual peak load to the system peak load.

SETTING UP THE GENERATOR

In setting up the generator first try to place the equipment near points of large demand, in order to reduce the size of wire required, to hold the line-losses to a minimum and to afford adequate voltage control at the remote ends of the lines. Generators must not be closer than 25 feet to a load, however.

If you are to select the site upon which the generator is to be set up, study a plot or chart of the area on which the individual buildings and facilities (demand) have been plotted. The site you select should be large enough to meet present and anticipated needs. It should be clear, level, dry, and well drained. If this type of site is not available, mount the generator set on a suitable foundation and bolt it down to eliminate any unnecessary vibration.

SHELTERING GENERATORS

Although advanced base portable generators are designed to be operated outdoors, prolonged exposure to wind, rain, and other adverse weather conditions will definitely shorten their life. If the generators are to remain on the site for any extended period of time, they should be mounted on solid concrete foundations and should be installed under some type of shelter.

There are no predrawn plans for shelters for a small advanced base generating station. The shelter will be an on-the-spot affair, the construction of which is determined by the equipment and material on hand plus your ingenuity, common sense, and your ability to cooperate with men in other ratings. Before a Builder can get started on the shelter, you will have to inform him of such things as the number of generators to be sheltered; the dimensions of the generators; the method of running the generator load cables from the generator to the bus bar and from the bus bar to the feeder system outside the building; and the arrangement of the exhaust system.

Installation specifications necessary for shelter plans can be obtained from the manufacturer's instruction manual that accompanies each unit. The following hints and suggestions will also be helpful.

1. Ventilation is an important factor to consider when installing the units inside a building. Every internal combustion engine is a HEAT engine. And, although heat does the work, excess amounts of it must be removed if the engine is to function properly. This can be accomplished by setting the engine's radiator grill near an opening in the wall and providing another opening directly opposite the unit. In this manner, cool air can be drawn in and the hot air directed in a straight line outdoors. These openings can be shielded with adjustable louvers to prevent the entrance of rain or snow. In addition, when operating in extremely cold weather, the temperature in the room can be controlled by simply closing a portion of the discharge opening. Additional doors or windows should be provided in the shelter if the plants are installed in localities where

the summer temperatures exceed 80° F at any time.

2. Working space is another consideration. Be sure to provide sufficient space around each unit for repairs or disassembly and for easy access to the generator control panels.

3. The carbon monoxide gas present in the exhaust of the engine is extremely poisonous and must not be allowed to collect in a closed room. Therefore means must be provided to discharge the engine's exhaust to the outdoors. This is done by extending the engine's exhaust pipe through the wall or roof of the building. Support the exhaust pipe and make certain that no obstruction or too many right angle bends are used. Also, whenever possible, arrange the exhaust system so that the piping slopes away from the engine. In this way, condensation will not drain back into the cylinders. If the exhaust pipe should have to be installed so that loops or traps are necessary, a drain cock should be placed at the lowest point of the system. All joints must be perfectly tight, and where the exhaust pipe passes through the wall, care must be taken to prevent the discharged gas from returning along the outside of the pipe back into the building.

Once the generating units have been set in place and bolted down, Builders can proceed to erect the building, using the necessary information with which they have been provided.

POWER (GENERATING) PLANT

As mentioned earlier in this chapter, generators of the advanced base type range in size from 1.5 kw to 600 kw. In this chapter we shall describe the lightweight 600 kw generator.

There are two types of 600-kw portable diesel electric generating plants: the heavyweight and the lightweight. The heavyweight is a 50-ton, medium-speed (720 rpm) plant, and the lightweight is a 45,500-pound, high-speed (1200 rpm) plant.

The large, heavyweight slower speed generator is more costly to install but more economical to operate and maintain. It is generally installed in projects having a life expectancy of 5 or more years. The large, high speed lightweight generator is cheaper to install but is more expensive to operate and maintain. This generator is generally used for projects with a life expectancy of less than 5 years.

The lightweight 600-kw portable diesel generator (fig. 6-5) has an overall width of 115 inches; an overall height from the bottom of the foundation to the top of the weatherproof housing of 104 inches; and an overall length of 24 feet.

The plant contains all components and accessories necessary to make a continuously operating unit that is capable of operating for at least 2 hours at 10 percent overload.

MAIN POWER UNIT

The engine is a Sterling Viking, 8-cylinder, 8-inch bore, 9-inch stroke, 4-cycle, solid-injection, supercharged diesel engine, with 1000 brake horsepower (bhp) maximum at 1200 rpm. The supercharger is of the Elliot exhaust-driven type, located at the flywheel end of the engine. Air intake of the supercharger is provided with an oil-wetted impingement cleanable-type air cleaner and silencer. Due to limitation of space, all parts of the engine requiring removal are of a size and weight that permit removal by hand, without the use of hoists or other type of lifting gear. An electric motor driven air compressor, arranged with a heavy duty Bendix engagement to the flywheel ring gear, is provided for cranking the engine while starting. Starting-air supply to the air-operated motor is controlled by a 12-volt heavy-duty solenoid valve that is placed in operation by a spring loaded pushbutton switch on the engine control panel. Provisions are made for controlling the lubrication of the air-operated motor.

GENERATOR

The main generator will deliver 600 kw of 2400/4160 volts, three-phase, 60-cycle alternating current to the bus at 0.8 power factor, exclusive of power consumed by accessories. The generator, is of a single-bearing construction with a forged flanged shaft, and is air cooled, drip proof, and self-ventilated; it operates at 1200 rpm, as mentioned previously. The exiter is directly connected to the free end of the main generator rotor. The generator set is designed to operate in parallel with other units of the same rating and manufacture.

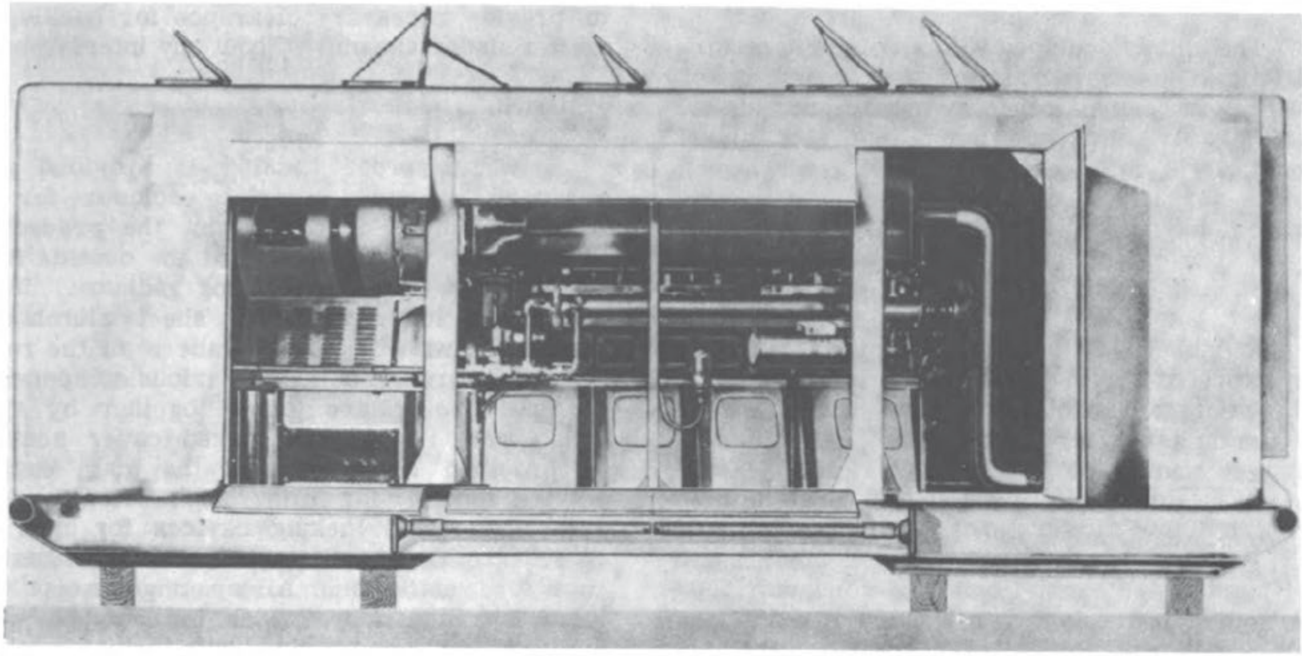

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Figure 6-5.—600-kw portable power plant, lightweight highspeed type.

AUXILIARY DIESEL ENGINE-GENERATOR SET

The auxiliary generator set has an output capacity of 6 kw of 120/208-volts, three-phase, 60-cycle, 4-wire alternating current. The engine is a 4-cycle, solid injection diesel. This unit is connected to a bus in the main generator switch-gear. It supplies current for all internal lighting, heating devices, battery charging rectifier, and motors required for the operation of the air compressor (for starting the main generator) and main engine lubricating oil filter circulating pump. Provisions are made to prevent interconnection of the auxiliary unit with main generator current supply or external power source.

STORAGE BATTERY

The unit is provided with a 12-volt storage battery capable of delivering 75 amperes for 6 hours or 450 ampere-hours. The battery supplies the direct current to the main engine speed-regulating governor motor, the emergency interior lighting system, the engine safety control operating devices, the auxiliary 6-kw generator starting motor, and to the main engine jacket fuel oil-fired water heater, fuel pump, and igniter. A selenium-rectifier type battery charger is provided, for operation on 120-volt, 60-cycle single-phase a-c and has a 12-volt d-c charging rate of 65 amps maximum with 18/25 amp minimum.

MAIN ENGINE JACKET WATER HEATER

A heater is located in the jacket cooling water system to provide heat to the main engine for cold weather conditions. The heater is operated by engine fuel oil and is capable of transmitting 60,000 btu per hour to the engine jacket water. The heater is equipped with various switches and controls for automatic operation.

UNIT HEATER

A unit type electric heater, with an air circulating fan, arranged for operation on 110-volt 60-cycle current having a capacity of 3000 watts is mounted in the end of the housing. This heater will circulate warm air when the plant is out of operation or in storage and will prevent interior condensation, or sweating. It is equipped with a wall-mounted thermostat having a temperature control of 40° to 80° F, supplied with a suitable ON-OFF switch.

AIR COMPRESSOR

The unit is equipped with an electric motor-driven, two-staged, aircooled air compressor having an actual capacity of 6.8 cfm at 250 psi to air start the main generator diesel engine. The compressor is driven by a 208-volt, three-phase, 60-cycle splashproof electric motor having a capacity of 2 horsepower.

CABLE REEL AND CABLE

A cable reel mounted on bearings is located in front of the radiator to furnish storage of the necessary cables for connections between the main generator control switchgear terminals and connected power source. The cable reel is of welded-tube construction to minimize restriction of air flow to the radiator.

The reel is furnished with one 50-ft length of number 4/0 extra-flexible, 3-conductor 5000 volt portable cable with ground wire for the main power supply. Suitable clamp-type terminals are furnished on each end of the cable. One 50-ft length of number 8 extra-flexible, 3-conductor 600-volt portable cable with ground wire is also provided for auxiliary purposes. This cable is equipped with a coupler plug at one end and a clamp-type terminal on the other. Two 25-ft lengths of number 2/0 extra-flexible portable cable, and number 2/0 600-volt neoprene-sheathed grounding conductors are provided with each plant.

MECHANICAL STRUCTURE OF THE 600-KW GENERATOR

The generator is equipped with a skid of welded steel construction, substantially ribbed and braced to a suitable base or foundation (see fig. 6-6). The unit has lifting pads installed for three point suspension. The skid is equipped with two tubular members which extend the full width of the base and are welded in a position to carry maximum weight for lifting the unit. The unit is equipped with four screw jacks that are constructed and mounted on tubular steel sections and arranged for insertion into the previously described tubular members welded into the base. The jacks can be locked in a vertical position when pulled out for lifting of the unit. Provision is also made for securing the lifting jacks when they are not in use and have been pushed back in horizontal position. Arrangement of the jacks will allow for lifting the entire unit 42 inches vertically, to provide necessary clearance for backing a trailer under the unit without any interference.

HOUSING

A weatherproof housing is provided and arranged to form a complete enclosure for all the equipment outlined in the preceding paragraphs, with exception of the outside face of the main generator cooling radiator. This housing is constructed of sheet aluminum, reinforced with bracing members on the roof, side and corner sections. Various components of the housing are joined together by spot welds and rivets. A hinged cover section is provided at the top of the main engine cooling radiator for filling. Eight hatch covers, with hinges and locking devices for open or closed position, are provided on the housing roof for ventilation. All openings except the main entrance door, which is equipped with lock and key, are provided with locking latches operable only from the inside of the housing. The main entrance door is provided with a folding platform and adjustable ladder which can be folded and stored when the unit is not in use or being transported.

INSPECTING THE GENERATOR AND SERVICING THE PRIME MOVER

After setting up a portable generator, your crew must do some preliminary work before placing the generator in operation. First they should make a visual overall inspection of the generator particularly the alignment. Have them look for broken or loose electrical and hose connections, loose bolts and capscrews and see that the ground plate is properly grounded. If any wire connection is suspected of being improperly connected, check it against the wiring diagrams in the instruction manual furnished with the generator. Any faults that are found should be corrected immediately.

Servicing the prime mover is the next step in the process of placing the generator in operation. Be sure that the crankcase is filled with the proper grade of oil and lubricant. A lubrication chart in the instruction manual furnished with each generator will show the proper grade of oil to use in accordance with the operating temperature. If the plant is to be operated in freezing temperatures

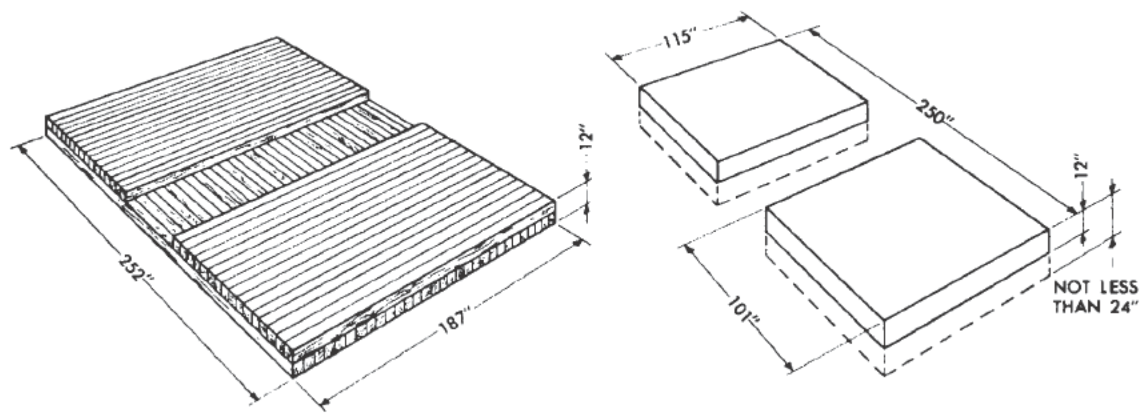

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Figure 6-6.—Suggested foundation.

be sure the men use an antifreeze solution in the proportions recommended in the generator's instruction manual.

The fuel tank should be filled with clean fuel oil. The fuel should be strained if necessary.

Some of the prime movers of advanced base electric power generators are started by starting units which obtain their power from batteries. If the prime mover that you are installing is equipped with a battery (or batteries) your crew has another servicing job to do. Batteries are usually shipped without the electrolyte, but with the plates in a dry-charged condition. Thus, it is necessary to fill the battery with electrolyte. Usually, the electrolyte is shipped right with the generator and is of the correct specific gravity. However, if you must prepare your own electrolyte use the mixing chart in table 6-2.

Because specific gravity of the electrolyte depends on the type of battery furnished with the generator, use the specific gravity value as recommended by the manufacturer's instruction manual. Generally, you will find that batteries with wood separators require an electrolyte with a specific gravity of 1.255 and batteries with rubber separators a specific gravity of 1.200.

After the electrolyte has been prepared, follow the manufacturer's instruction manual with regard to the recommended filling procedure. In the event the manual is not available, have your men use the following general procedure:

1. Add electrolyte to each of the battery's cells until the level of the electrolyte is visible in the filler neck or at least 3/8 inch above the separators. The temperature of the electrolyte when placed in the cells should be between 60° and 90° F. IT SHOULD NEVER EXCEED 90° F.

2. Chemical reaction resulting when filling the battery will cause the battery to heat. It may be cooled artificially (cooling fans) or allowed to stand at least 1 hour before placing it in service.

3. You will probably notice at the end of the cooling period that the level of the electrolyte has dropped. This is due to the electrolyte

Table 6-2.—Electrolyte Mixing Chart

Specific gravity desired	Using 1.835 specific gravity acid		Using 1.400 specific gravity acid	
	Parts of water	Parts of acid	Parts of water	Parts of acid
1.400	3	2	..	..
1.345	2	1	1	7
1.300	5	2	2	5
1.290	8	3	9	20
1.275	11	4	11	20
1.250	13	4	3	4
1.225	11	3	1	1
1.200	13	3	13	10

soaking into the plates and separators. Before placing the battery in service restore the electrolyte to its proper level.

4. Any electrolyte spilled on the battery should be removed with a cloth dampened with a solution of bicarbonate of soda and water.

Although the battery can be placed in service 1 hour after filling it with electrolyte, it is a procedure that you should consider only in an emergency. If at all possible, the battery should be given an initial light charge. If the charging procedure is not covered in the manufacturer's instruction manual, use the following general procedure:

1. Charge the battery at a low rate (about 5 amperes) until the voltage and specific gravity corrected to 80° F, remains constant for at least 5 hours.

2. If the temperature of the electrolyte reaches 125° F, reduce the charging rate or stop the charge until the battery cools.

3. During charging replenish any water lost by evaporation.

After the battery has been charged, it is connected into the starting system of the prime mover as indicated by the wiring diagrams accompanying the generator.

On the 600-kw generator you should check the ventilation; the fan cover must be opened and latched in that position. There must be no cover or obstructions over the main diesel engine exhaust stacks, or over the radiator section. The bypass shutters or doors may be opened to shorten the warming up period, and roof hatches and side louvers MAY be opened for additional ventilation, if required.

ALTERNATOR INSPECTION AND SERVICING

Just as important as the preparation of the prime mover is the inspection and servicing of the alternator. Generally, you should have your men take the following steps:

1. Check all the electrical connections by referring to the generator's connection diagrams.

2. See that connections are tight.

3. See that the collector rings are clean and have a polished surface.

4. Check collector brushes to make sure they have no tendency to stick in the brush holders, that they are properly located, and that the pigtails will not interfere with the brush rigging.

5. Check the collector brush pressure to see if it agrees with the figure recommended in the manufacturer's instruction manual. When the brush pressure information is not available, use a brush pressure of approximately 2 psi of brush area.

6. Check the exciter in the same manner as the alternator.

ELECTRICAL CONNECTIONS

While the electric generator is being installed and serviced, a part of your crew can connect it to the load. Essentially, this consists of running wire or cable from the generator to the load. At the load end, the cable is connected to the equipment or to the interior wiring system of the building. At the generator end, the cable is connected either to the output terminals of a main circuit breaker or a branch circuit breaker. When the wire is run and connections are made it will be up to you to:

1. Decide whether the wire or cable will be buried or carried overhead on poles.

2. Determine the correct size of wire or cable to use.

3. Check the generator lead connections of the plant to see that they are arranged for the proper voltage output.

The information contained in the following sections will help you in these tasks.

Installing the Load Cable

The load cable may be installed overhead or underground. In an emergency installation, time is the important factor. It may be necessary to use trees, pilings, four-by-fours or other temporary line supports to complete the installation. Such measures are temporary; eventually, you will have to erect poles and string the wire on crossarms or bury it underground. If the installation is near an airfield, it may be necessary to place the wires underground at the beginning. Wire placed underground should be rubber insulated, rubber jacketed cable; otherwise, it will not last long.

Direct burying of cable for permanent installation calls for a few simple precautions to ensure uninterrupted service. They are:

1. Dig the trench deep enough so that the cable can be buried at least 18 inches (24 inches in traffic areas and under roadways) below the surface of the ground to prevent

disturbance of cable by frost or subsequent surface digging (fig. 6-7).

2. Lay the cable over a sand cushion (fig. 6-7). If this is impractical, loosen the trench base so it is cleared of rocks and stones.

3. Space the cables on 6-inch centers for further mechanical and electrical protection (fig. 6-7).

4. After laying the cable and before backfilling, cover it with earth free from stones, rocks etc. This will prevent the cable from being damaged in the event the surrounding earth is disturbed by flooding or frost-heaving.

Determining Cable Size

If the wrong size conductor is used in the load cable, various troubles may occur. If the conductor is too small to carry the current demanded by the load, it will heat up and possibly cause a break in the circuit. A fire might result from this excess heat or break in the circuit. Even though the conductor is large enough to safely carry the load current, its length might result in a lumped resistance that produces an excessive voltage drop. An excessive voltage drop results in a reduced voltage at the load end that is incapable of operating the equipment. In this respect it might be well to point out that voltage drop should not exceed 3 percent for power loads and 1 percent for lighting loads or combined power and lighting loads. For example, if a generator generates 400 volts for power equipment, the voltage drop in the line should not exceed 13.2 volts (440 x 0.03).

To determine size, then, you must consider (1) the load current to be carried by the cable, and (2) the distance between the load and the generator. Generally, the following steps shown in tables 6-3 and 6-4 are involved:

Step 1. Compute the total current demand with the aid of tables 6-3 and 6-4.

Step 2. Use table 6-5 to find the size cable capable of carrying this total current.

Step 3. Use table 6-6 to determine what the lumped resistance of the cable will be when stretched between the generator and the load.

Step 4. Compute the voltage drop in the cable with the information obtained in step 3.

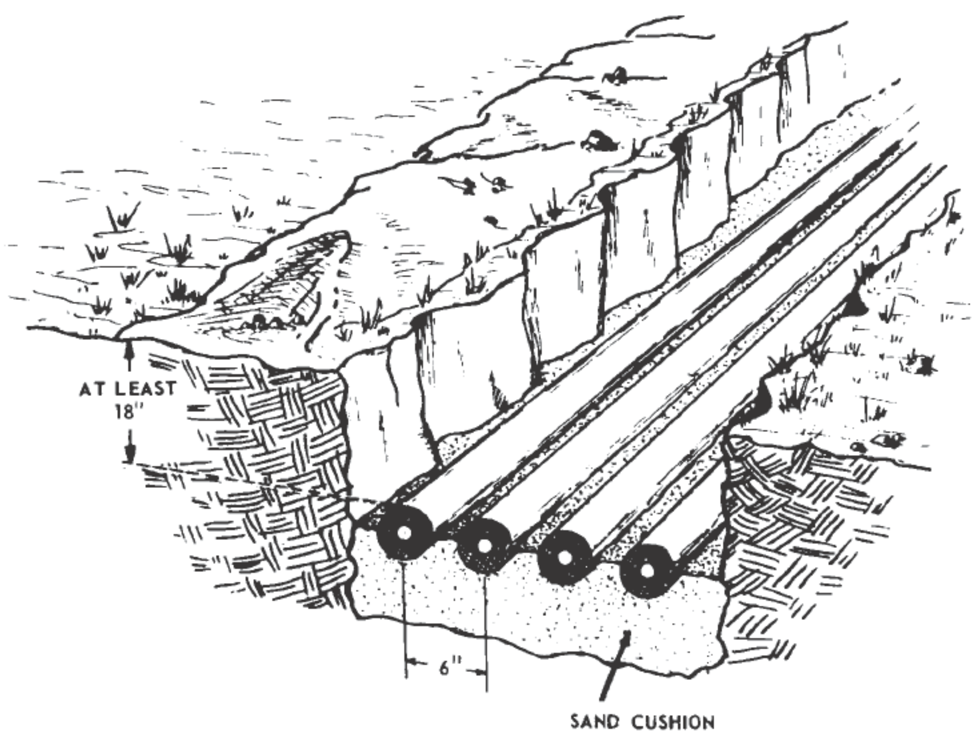

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Figure 6-7.—Direct burial of cable showing proper cable spacing and depth.

To find—	Direct current	Alternating current	
		Single-phase	† Three-phase
Amperes when horsepower (input) is known	$\frac{\text{H. P. x 746}}{\text{Volts x effcy. (\%)}}$	$\frac{\text{H. P. x 746}}{\text{Volts x effcy. (\%) x P. F.}}$	$\frac{\text{H. P. x 746}}{\text{Volts x 1.73 x effcy. (\%) x P. F.}}$
Amperes when kilowatts is known	$\frac{\text{Kw. x 1,000}}{\text{Volts}}$	$\frac{\text{Kw. x 1,000}}{\text{Volts x P. F.}}$	$\frac{\text{Kw. x 1,000}}{\text{Volts x 1.73 x P. F.}}$
Amperes when Kv.-a. is known		$\frac{\text{Kv.-a. x 1,000}}{\text{Volts}}$	$\frac{\text{Kv.-a. x 1,000}}{\text{Volts x 1.73}}$
Kilowatts	$\frac{\text{Amperes x volts}}{\text{1,000}}$	$\frac{\text{Amps. x volts x P. F.}}{\text{1,000}}$	$\frac{\text{Amps. x volts x 1.73 x P. F.}}{\text{1,000}}$
Kv.-a		$\frac{\text{Amps. x volts}}{\text{1,000}}$	$\frac{\text{Amps. x volts x 1.73}}{\text{1,000}}$
Power factor	(P. F.)	$\frac{\text{Kilowatts}}{\text{Amps. x volts} \div \text{1,000}}$ or $\frac{\text{Kilowatts}}{\text{Kv.-a.}}$	$\frac{\text{Kilowatts}}{\text{Amps. x volts x 1.73} \div \text{1,000}}$ or $\frac{\text{Kilowatts}}{\text{Kv.-a.}}$
Horsepower (output)	$\frac{\text{Amps. x volts x effcy. (\%)}}{\text{746}}$	$\frac{\text{Amps. x volts x effcy. (\%) x P. F.}}{\text{746}}$	$\frac{\text{Amps. x volts x 1.73 x effcy. (\%) x P. F.}}{\text{746}}$

Power factor (P. F.) as used in formulas is expressed as a decimal except in the case of unity power factor which is expressed as 1.0.

† For 2-phase, 4-wire substitute 2 instead of 1.73.

† For 2-phase, 3-wire substitute 1.41 instead of 1.73.

Table 6-3.—Conversion formulas.

The following data are approximate full-load currents for motors of various types, frequencies, and speeds. They have been compiled from average values for representative motors of their respective classes. Variations of 10 percent above or below the values given may be expected.

Hp. of motor	Amperes — Full-load current																								
	Direct-Current motors			Alternating - Current motors																					
				Single-phase motors		Squirrel-cap induction motors										Slip-ring induction motors									
						Two-phase					Three-phase					Two-phase					Three-phase				
	115-volt	230-volt	550-volt	110-volt	220-volt	110-volt	220-volt	440-volt	550-volt	2,200-volt	110-volt	220-volt	440-volt	550-volt	2,200-volt	110-volt	220-volt	440-volt	550-volt	2,200-volt	110-volt	220-volt	440-volt	550-volt	2,200-volt
1/4	----	----	----	4.8	2.4	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1/2	4.5	2.3	----	7	3.5	4.3	2.2	1.1	0.9	----	5.0	2.5	1.3	1.0	----	----	----	----	----	----	----	----	----	----	----
3/4	6.5	3.3	1.4	9.4	4.7	4.7	2.4	1.2	1.0	----	5.4	2.8	1.4	1.1	----	6.2	3.1	1.6	1.3	----	7.2	3.6	1.8	1.5	----
1	8.4	4.2	1.7	11	5.5	5.7	2.9	1.4	1.2	----	6.6	3.3	1.7	1.3	----	6.7	3.4	1.7	1.4	----	7.8	3.9	2.0	1.6	----
1-1/2	12.5	6.3	2.6	15.2	7.6	7.7	4.0	2	1.6	----	9.4	4.7	2.4	2.0	----	11.7	5.9	3.0	2.3	----	----	----	----	----	----
2	16.1	8.3	3.4	20	10	10.4	5	3	2.0	----	12.0	6	3.0	2.4	----	12.5	6.3	3.1	2.5	----	14.4	7.2	3.6	2.9	----
3	23	12.3	5.0	28	14	----	8	4	3.0	----	----	9	4.5	4.0	----	----	8.7	4.3	3.5	----	20.2	10	5.0	4	----
5	40	19.8	8.2	46	23	----	13	7	6	----	----	15	7.5	6.0	----	----	13.0	6.5	5.2	----	----	15	7.5	6	----
7-1/2	58	28.7	12	68	34	----	19	9	7	----	----	22	11	9.0	----	----	20.0	10.0	7.6	----	----	25	13	10	----
10	75	38	16	86	43	----	24	12	10	----	----	27	14	11	----	----	24.3	12.1	10.0	----	----	28	14	11	----
15	112	56	23	----	----	----	33	16	13	----	----	38	19	15		----	39	19.5	15.6	----	----	45	23	18	----
20	140	74	30	----	----	----	45	23	19	----	----	52	26	21	5.7	----	49	24.7	19.8	----	----	56	28	22	----
25	185	92	38	----	----	----	55	28	22	6	----	64	32	26	7	----	60	30.0	24.0	6.4	----	67	34	27	7.5
30	220	110	45	----	----	----	67	34	27	7	----	77	39	31	8	----	72	36.0	28.8	7.8	----	82	41	33	9
40	294	146	61	----	----	----	88	44	35	9	----	101	51	40	10	----	93	46.5	37.3	9.5	----	106	53	42	11
50	364	180	75	----	----	----	108	54	43	11	----	125	63	50	13	----	113	57	45	12.1	----	128	64	51	14
60	436	215	90	----	----	----	129	65	52	13	----	149	75	60	15	----	135	68	54	14.0	----	150	75	60	16
75	540	268	111	----	----	----	156	78	62	16	----	180	90	72	19	----	164	82	65	17.3	----	188	94	75	19
100	----	357	146	----	----	----	212	106	85	22	----	246	123	98	25	----	214	108	87	21.7	----	246	123	99	25
125	----	443	184	----	----	----	268	134	108	27	----	310	155	124	32	----	267	134	108	27	----	310	155	124	31
150	----	----	220	----	----	----	311	155	124	31	----	360	180	144	36	----	315	158	127	32	----	364	182	145	37
175	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
200	----	----	295	----	----	----	415	208	166	43	----	480	240	195	49	----	430	216	173	44	----	490	245	196	52

Table 6-4.—Full load currents of motors

Not More Than Three Conductors in Raceway or Cable (Based on Room Temperature at 30 C. (86 F.)

Size AWG or MCM	B	C	D	E	F	G
	Rubber Type R type RW type RU (14-6) / Thermo-plastic type T (14-4/0) type TW (14-4/0)	Rubber Type RH	Paper / Thermo-plastic asbestos type TA / Var-cam type V / Asbestos var-cam type AVB	Asbestos var-cam type AVA type AVL	Impreg-nated asbestos type AI (14-8) type AIA	Asbestos type A (14-8) type AA
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340
250	215	255	270	315	335	---
300	240	285	300	345	380	---
350	260	310	325	390	420	---
400	280	335	360	420	450	---
500	320	380	405	470	500	---
600	355	420	455	525	545	---
700	385	460	490	560	600	---
750	400	475	500	580	620	---
800	410	490	515	600	640	---
900	435	520	555			
1,000	455	545	585	680	730	---
1,250	495	590	645	---	---	---
1,500	520	625	700	785	---	---
1,750	545	650	735	---	---	---
2,000	560	665	775	840	---	---

Correction factor for room temperatures over 30 C. (86 F.)

°C.	°F.	B	C	D	E	F	G
40	104	0.82	0.88	0.90	0.94	0.95	---
45	113	.71	.82	.85	.90	.92	---
50	122	.58	.75	.80	.87	.89	---
55	131	.41	.67	.74	.83	.86	---
60	140	---	.58	.67	.79	.83	0.91
70	158	---	.35	.52	.71	.76	.87
75	167	---	---	.43	.66	.72	.86
80	176	---	---	.30	.61	.69	.84
90	194	---	---	---	.50	.61	.80
100	212	---	---	---	---	.51	.77
120	248	---	---	---	---	---	.69
140	284	---	---	---	---	---	.59

Table 6-5.—Allowable current-carrying capacities of conductors in amperes

Standard stranded conductor		I. P. C. E. A. class B	Resistance ohms 1,000 ft. at 25°C. (77° F.)	
Size AWG	Circular mils	Number of wires	Bare copper	Tinned copper
18	1,624	7	6.64	7.05
16	2,583	7	4.18	4.43
14	4,107	7	2.63	2.69
12	6,530	7	1.65	1.72
10	10,380	7	1.04	1.08
9	13,090	7	0.824	0.856
8	16,510	7	0.654	0.679
7	20,820	7	0.519	0.538
6	26,250	7	0.410	0.427
5	33,100	7	0.326	0.339
4	41,740	7	0.259	0.269
3	52,640	7	0.205	0.213
2	66,370	7	0.162	0.169
1	83,690	19	0.129	0.134
1/0	105,500	19	0.102	0.106
2/0	133,100	19	0.0811	0.0842
3/0	167,800	19	0.0642	0.0668
4/0	211,600	19	0.0509	0.0525
---	250,000	37	0.0431	0.0449
---	300,000	37	0.0360	0.0374
---	350,000	37	0.0308	0.0320
---	400,000	37	0.0270	0.0278
---	450,000	37	0.0240	0.0247
---	500,000	37	0.0216	0.0222
---	550,000	61	0.0196	0.0204
---	600,000	61	0.0180	0.0187
---	650,000	61	0.0166	0.0171
---	700,000	61	0.0154	0.0159
---	750,000	61	0.0144	0.0148
---	800,000	61	0.0135	0.0139
---	900,000	61	0.0120	0.0123
---	1,000,000	61	0.0108	0.0111
---	1,250,000	91	0.00863	0.00888
---	1,500,000	91	0.00719	0.00740
---	1,750,000	127	1.00616	0.00634
---	2,000,000	127	0.00539	0.00555

Table 6-6.—Physical properties of conductors

Step 5. Compare this voltage drop to the maximum figure allowed; that is, 3 percent for power load and 1 percent for lighting load or light and power combined.

Perhaps an example will help. A rough sketch of a typical emergency installation is shown in figure 6-8. A 30-kw, diesel-engine driven generator is supplying on the spot power to electrical equipment located 50 feet away. The voltage output of the generator is 127/220 volts and is to be carried over to the equipment via four single-conductor rubber-jacket cables.

The first step is to compute the total load current. This will be the sum of the current required by the individual pieces of electrical

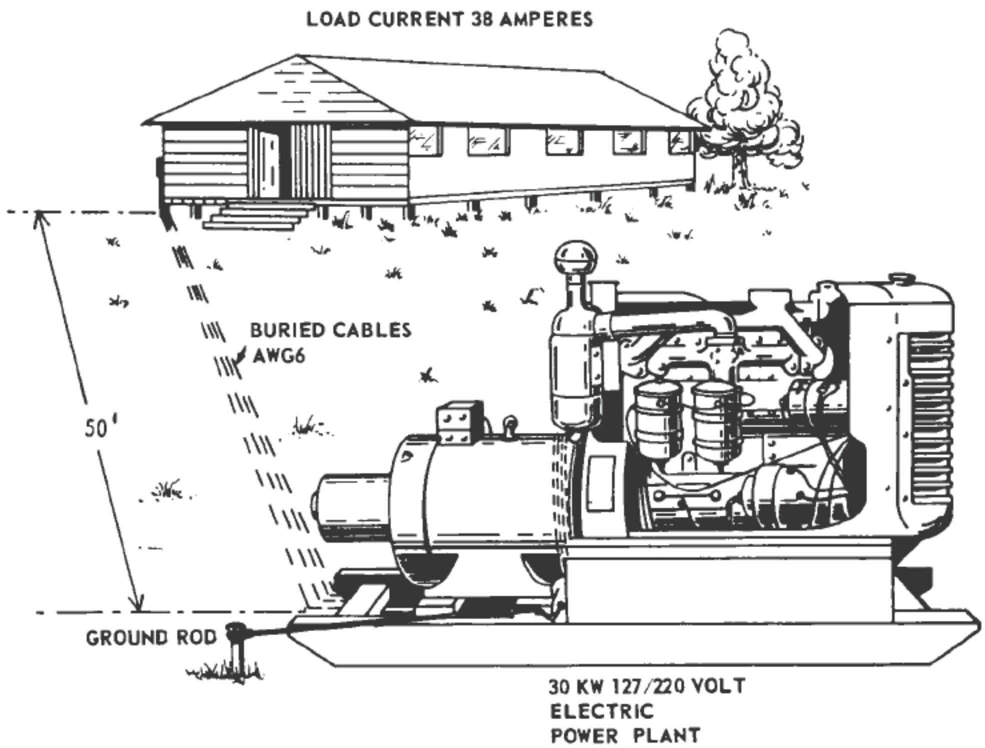

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Figure 6-8.—Determining wire size.

equipment. In this particular example you find the following:

Twelve 100-watt, 120-volt lamps.

One 10-horsepower, 220-volt, three-phase, slip-ring induction motor.

Twelve 100-watt lamps require a total power input of 1200 watts or 1.2 kw. (12 x 100 watts). Table 6-3 indicates that to find amperes when kilowatts are known for single-phase a-c circuits the following formula should be used:

$$I = \frac{\text{kw.} \times 1000}{\text{volts} \times \text{power factor}} \quad \text{(P.F. for lighting circuits is 1)}$$

Therefore, by substitution

$$I = \frac{1.2 \times 1000}{120 \times 1} = 10 \text{ amperes for the lamps}$$

This takes care of the lighting load. Now figure the current required by the motor. Table 6-4 shows that a 10-horsepower, 220-volt, three-phase, induction motor has a full-load current of 28 amperes.

Summing up the individual current demands of the equipment you have:

Twelve 100-watt lamps- - -	10 amps
One 10-horsepower 220-volt three-phase slip-ring induction motor - - - - - - - -	28 amps
Total load current =	38 amps

The second step is to choose the cable capable of carrying 38 amperes. Table 6-5 will help you. It lists the allowable current-carrying capacities of conductors of different sizes with different insulation coverings. You are installing under ground cable that has a moisture-resistant rubber covering, type RW. Therefore you will use column B of the table. Follow column B down until you reach an ampere value that is greater than 38 amperes. In this case you find a value of 40 amperes. However, since 38 amperes is so close to 40 amperes you should choose the next ampere value (55) to allow for possible additions to the load. Column A indicates that conductor size AWG No. 6 is capable of carrying 55 amperes.

Step three is to find the amount of resistance that the load current will meet if you used No. 6 cable. Table 6-6 lists the physical properties of stranded conductors. It shows that a No. 6 tinned copper conductor possesses 0.427 ohms of resistance in every 1000 feet. The cable is to run a distance of 50 feet between the plant and the load. However, since the current must travel both ways it will actually pass through 100 feet of cable. Therefore, the total amount of resistance it will meet will be:

$$R = \frac{0.427 \times 100}{1000} = 0.0427 \text{ ohms}$$

In step four you are to find the voltage drop in the cable. All it takes is a simple application of Ohm's law.

$$E \text{ (voltage drop)} = I \text{ (load current)} \times R \text{ (cable resistance)}$$

$$\text{or } E = 38 \times 0.0427 = 1.62 \text{ volts}$$

In step five you compare the actual voltage drop that will occur in the cable with the value allowed. The voltage drop in the cable (step 4) is 1.62 volts. The maximum voltage drop allowed for a combined lighting and power circuit is 1 percent of the source voltage. In this case the power plant generates 220 volts. Therefore the voltage drop should not exceed 2.2 volts (220x0.01). You can see that the actual voltage drop (1.62 volts) is well within this limit, so you can use a AWG No. 6 cable and meet all requirements. If the actual voltage drop had been greater than the allowable value it would be necessary to use the next larger size cable.

Generator Connections

When you install a power plant that has a dual-voltage alternator unit, you must make certain that the armature coil leads are properly connected to produce the voltage required by the equipment. Take a look at figure 6-9. It shows an alternator unit that has been disconnected and removed from a three-phrase diesel driven power plant. Plainly visible are the stationary armature coils and core (stator) mounted in the main frame of the generator. The a-c voltages generated in the coils are brought through an opening in the pedestal of the frame by means of 10 coil leads. Each coil lead is identified by a number stamped on a metal band.

In 220/440-volt dual-voltage, three-phase generators the voltage generated in each set of coils, when the prime mover is operating at rated speed, is 127 volts. Thus, by connecting the external coil leads together in different combinations, you can change the external voltage output of the generator. The chart in table 6-7 gives the exact data needed to make these connections for both three-phase and single-phase voltage outputs.

Let's take a specific example. Suppose it becomes necessary to obtain 220-volts single-phase from a three-phase, dual-voltage generator. Checking table 6-7 you find that coil leads T2 and T8 are to be connected together and then in turn, connected, through the main circuit breaker, to one of the two load cables. Similarly coil leads T3 and T9 are to be secured and connected, through the main circuit breaker, to the other load cable. Terminal lugs on the end of each coil lead provide an easy means of bolting them together. Just be sure that the connections are thoroughly insulated with a wrapping of rubber tape followed by a wrapping of friction tape. Table 6-7 indicates that leads T1, T4, T7, and T0 are not used for single-phase service. Therefore, to finish the job, you should individually insulate each of these four leads with rubber and friction tape. Figure 6-10(a) shows you how the connections appear on the stator coil diagram. Figure 6-10(b) shows the appearance of the actual connections.

RECONNECTING GENERATOR LEADS

When you reconnect generator leads to meet certain load conditions, you change not only the voltage output of the generator but also its current rating. These voltage and current changes will have an effect on the operational characteristics of the switchboard controls and instruments. Thus, before the generator can be put into operation, certain internal alterations must be affected.

For example, suppose that it becomes necessary to reconnect a 75-kw., three-phase, 220-volt generator so that it will have an output voltage of 440 volts. In its original connection (220-volt output), the generator was capable of carrying a full-load current of 264 amperes. Changing over to 440 volts, however, reduces its full-load current to 132 amperes. The first

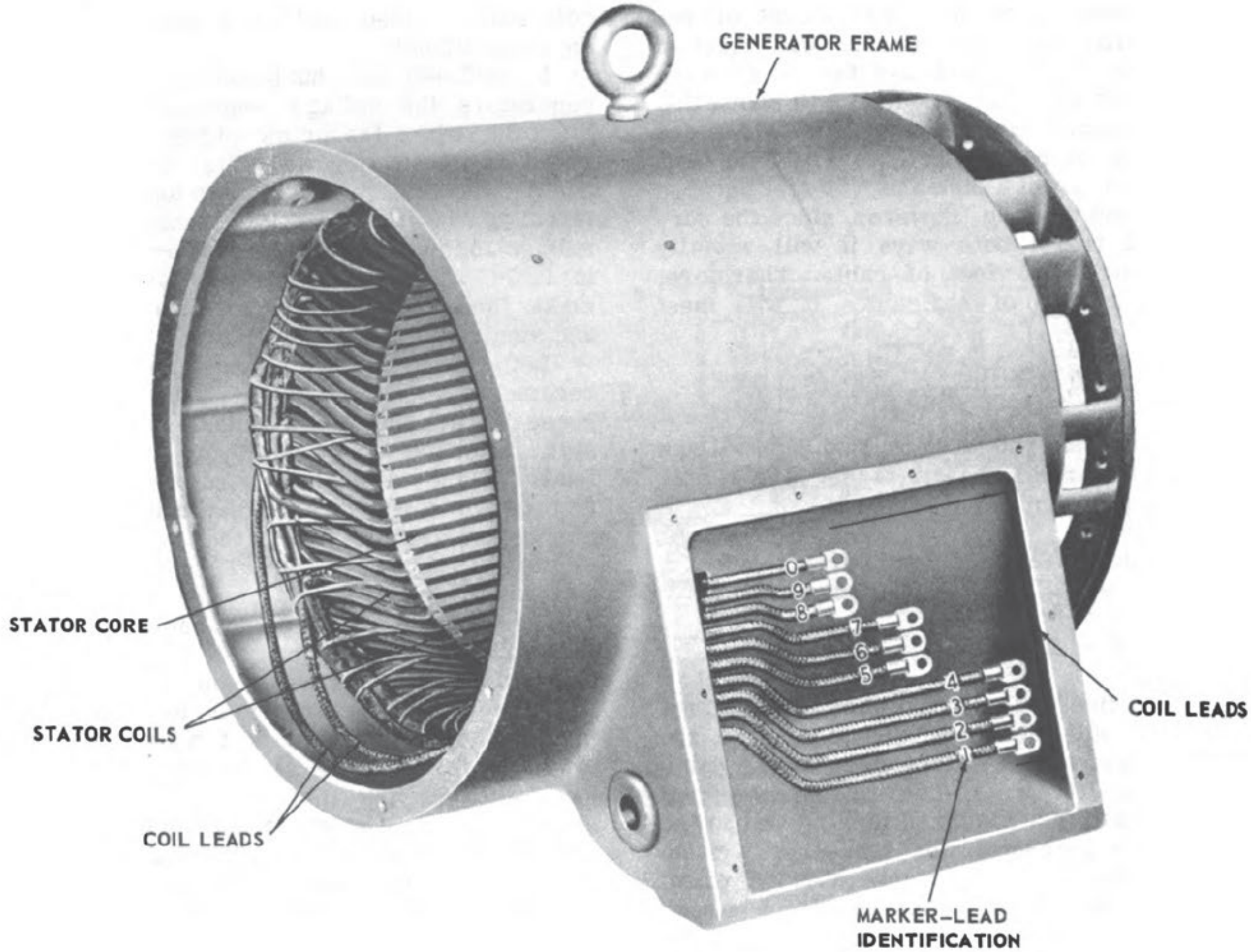

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Figure 6-9.—Alternator coil leads.

thing you will want to check, then, is the fuse rating in the main circuit breaker. You will probably find that for its original connection—220 volts, 264 amperes—the generator was protected by a 275-ampere trip element (fuse). To protect the generator for its new current rating (132 amperes), it will be necessary to replace the 275-ampere fuse with one having a 150-ampere rating.

Another thing to consider when reconnecting a generator is the switchboard ammeter instrument that records the current output of the unit. Since it is impractical to use an ammeter capable of carrying the full-load current, instrument transfers are employed. The instrument transformer reduces the current value to one that may be safely measured by the ammeter. Usually, the instrument transformer is designed to reduce the full-load current to a secondary current of 5 amperes. In turn, the ammeter, which is connected to the transformer's secondary, is designed to produce a full-scale deflection with an input of 5 amperes. Since the ratio between the load current and the the current in the instrument transformer secondary is practically constant, the ammeter scale can be calibrated to read a true value of load current. Now, in the example being used, the generator has a full-load current of 264 amperes when it is connected for a 220-volt output. That means that the instrument transformer will induce 5 amperes of current in its full secondary winding when 264 amperes flows in the line and,

Required voltage	Connect line leads (via circuit breaker) to—			Connect	Tape individually
440-volts, three-phase, 3-wire.	T1	T2	T3	T4 to T7 T5 to T8 T6 to T9	
127/220-volts, three-phase, 4-wire.	T1 and T7	T2 and T8	T3 and T9	T4, T5, T6, and T0 for neutral.	
220-volts, single-phase, 2-wire.	T2 and T8	-------------	T3 and T9	T5 to T6	T1, T4, T7, T0.
220/440-volts, single-phase, 3-wire.	T3	T2 and T9, neutral.	T8	T5 to T6	T1, T4, T7, T0.
440-volts, single-phase, 2-wire.	T3	-------------	T8	T2 to T9 T5 to T6	T1, T4, T7, T0.

Table 6-7.—Connections for three-phase generators

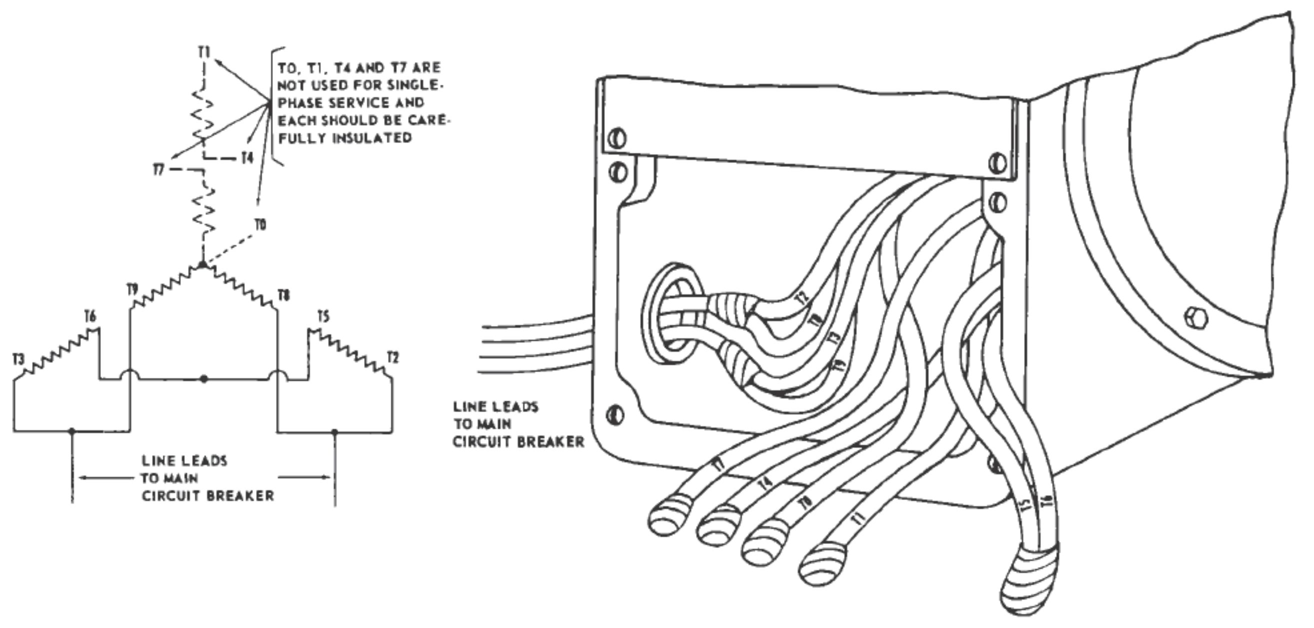

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Figure 6-10.—220-volt, single phase connections.

as a result, the ammeter will have a full-scale deflection. However, on reconnecting the generator for 440 volts, the full-load current is reduced to 132 amperes. Unless you alter the instrument transformer connections, full-load current will produce only a half-scale deflection of the ammeter and a resultant false reading. In this particular case, the alteration consists of moving the instrument transformer winding connection from the full-winding position to the mid-tap position. Most switchboard ammeters have an additional calibrated scale which makes it unnecessary to apply a correction constant when the current range is changed.

Another alteration that you may have to make in the generator's switchboard wiring concerns the voltage regulator. Essentially, the purpose of this device is to keep the generated voltage within certain limits regardless of changing load conditions. Although there are many types of voltage regulators they all respond to VARIATIONS IN RATED LINE VOLTAGE. However, the line voltage is not applied directly to the regulator unit. A potential transformer is employed to reduce the line voltage to a standard value that is safe to use on the regulator. The ratio of primary voltage to secondary voltage must remain constant if the regulator is to function properly within the limits of the generator's rated voltage. Therefore, when the output voltage of the generator is changed, you must also change the tap connections on the primary of the potential transformer.

Probably the big question in your mind is, "Do these alterations require that you actually dive into the maze of wiring behind the generator's switchboard and move leads from one terminal to another?" Generally no. In a few cases you may have to change the leads. The majority of manufacturers have made provisions that simplify the changeover from one voltage output to another. Typical of these changeover provisions is the generating set illustrated in figure 6-11. Essentially, it consists of a 6-bladed, double-throw VOLTAGE SELECTOR SWITCH mounted on a terminal board. As shown in the end view of the generating set (fig. 6-11), the terminal board is mounted in the lower right-hand corner of the frame. The three vertical rows of the switch contacts extend through the terminal board and are connected permanently, by means of wires, to the generator's stator coil leads; the current and potential transformer windings; the instruments and controls on the switchboard; and the circuit breaker. The arrangement of the wires is such that when the switch is thrown to the left the stator coil leads are automatically connected to produce an output

voltage of 220 volts, and the current and potential transformers windings are tapped at the correct point for proper operation of the switchboard's instruments and controls. When the selector switch is thrown to the right, the wiring arrangement automatically connects the stator coil leads for a 440-volt output and taps the instrument transformer windings for correct outputs in accordance with the generator's new voltage and current range.

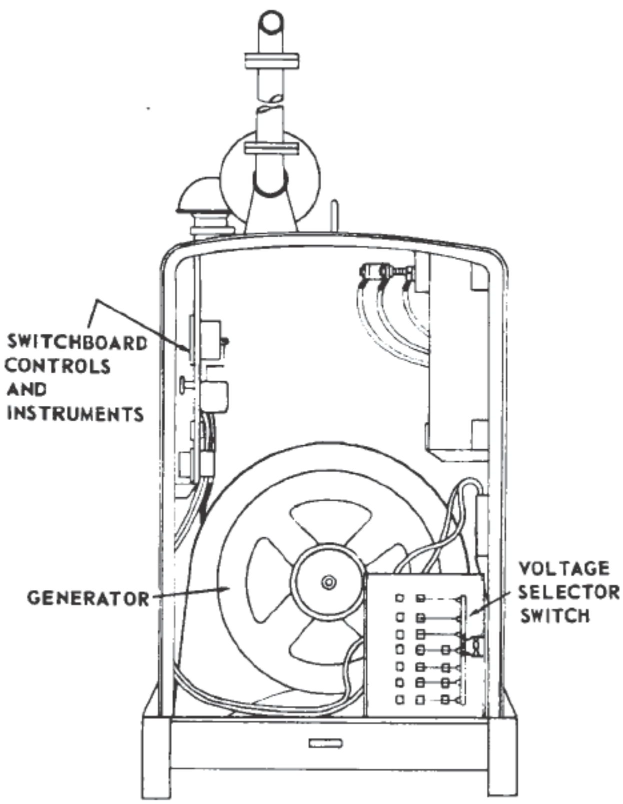

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Figure 6-11.—Voltage selector switch on a typical generating set.

One type of change-over device in advanced base generators is shown in figure 6-12. It is a CHANGEOVER BLOCK that is mounted on the rear of the generator's switchboard (control cabinet). The terminal studs that protrude from the changeover block serve two purposes: they provide a disconnect point between the load cables and the generator coil leads, and they present a convenient means of altering the operating characteristics of the generator's components without changing the positions of the wires. Notice that each of the 10 generator stator coil leads is attached to a correspondingly numbered terminal stud. Rearrangement of the coil leads becomes a simple process of interconnecting the terminal studs in a definite pattern by the use of CHANGEOVER LINKS (fig. 6-12). When in position on the coil lead terminal studs, the changeover links also contact other studs that are connected to such components as the current transformers, and the potential transformers. Thus, alteration of these components output is also changed automatically. Connection diagrams on a nameplate attached to the changeover block provide the necessary information as to the position of the changeover links for specific voltage outputs.

Remember that you are responsible for the proper operation of the generating unit. Therefore proceed with caution on any reconnection job. Study the wiring diagrams of the plant and follow the manufacturer's instructions to the letter. Before you start the plant up and throw the circuit breaker, do a double-check on all connections.

BUS BAR

There are a number of reasons why it is sometimes necessary to use a bus bar when you set up a portable generating station. For one thing, you may not be able to acquire a generating plant that has sufficient capacity to meet the total power demand of the electrical load. It will be necessary, then, to use two or more generating units and collect their paralleled outputs at one central point (the bus bar). Or, you may discover that the electrical equipment in the advanced base is scattered in such a manner as to require the use of feeder (branch) lines that can be controlled from a central source. Again, the bus bar is the answer.

A typical advanced base generating station using a bus bar is shown in figure 6-13 (circuit breakers are enclosed in the generator). The two generators are leveled on a concrete apron that is sloped for drainage. The electrical output of each generator is transferred underground to the bus bar by four, single-conductor cables. The bus bar itself consists of four cables stretched between two 4 by 4 posts. A secondary rack mounted on each post serves as an insulating support for the bus-bar cables. Two switches, one for each feeder line, are

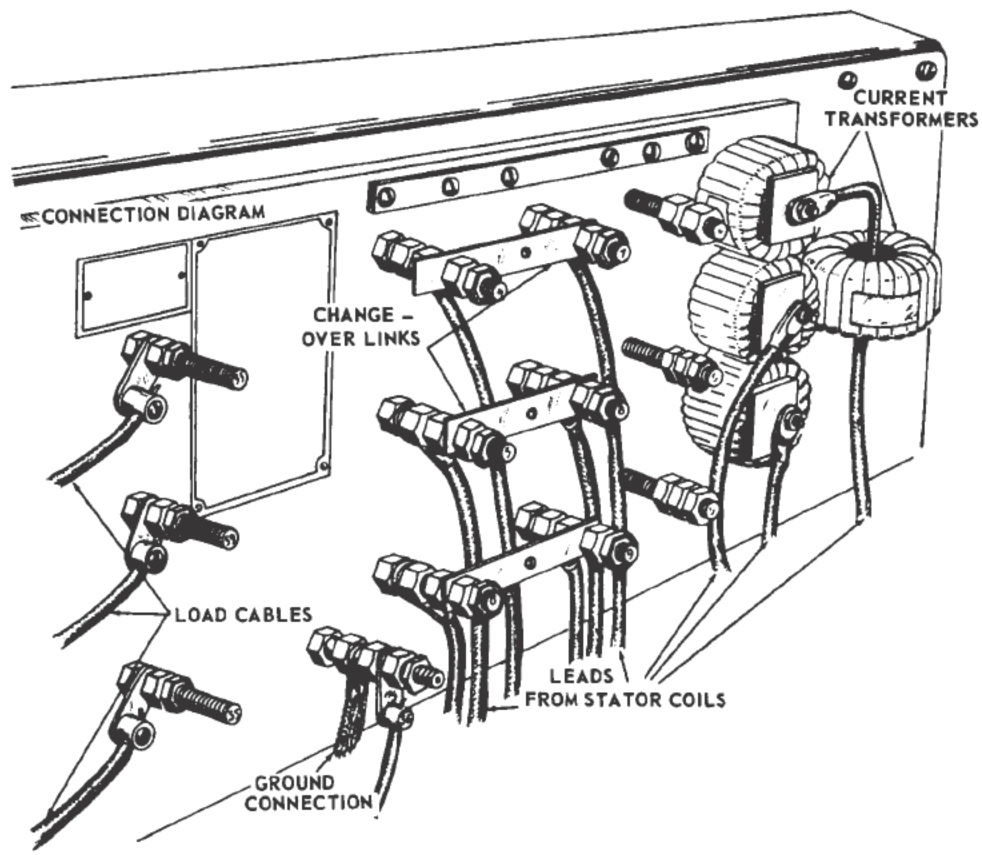

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Figure 6-12.—Typical changeover block showing generator and load connecting points.

mounted above the bus bar. A wooden platform provides an insulating medium for operating personnel.

Whether or not your bus-bar installation looks exactly like the one in figure 6-13, the point to remember is that the equipment should be properly secured and supported, and where necessary, properly insulated. The size of wire will depend on the load current. The switches that control the output to each feeder line can either be of the fused knife switch or the circuit-breaker type. Be sure that the current rating of the fuses or trip element will provide adequate protection against excessive overloads or short circuits on the feeder lines. Also make certain that the components of the circuit breaker or switch (i.e., the switch blades and breaker contacts) are capable of carrying the rated current and voltage of the feeder lines. In addition, make every effort to protect the switchgear and bus bar from the weather. Building a weatherproof canopy over the rack will help ensure uninterrupted service and protection for personnel.

POWER PLANT (GENERATOR) OPERATION

Setting up a power generator is only one phase of your job. After the plant is set up and ready to go, you will be expected to supervise the activities of the operating personnel of the generating station. In this respect, your supervision should be directed toward one ultimate goal—to maintain a continuous and adequate flow of electric power to meet the demand. This can be accomplished if you have a thorough knowledge of how to operate and maintain the equipment and a complete understanding of the station's electrical system as a whole. Obviously, a thorough knowledge of how to operate and maintain the specific equipment found in the generating station to which you are assigned cannot be covered here. However, general information can be given.

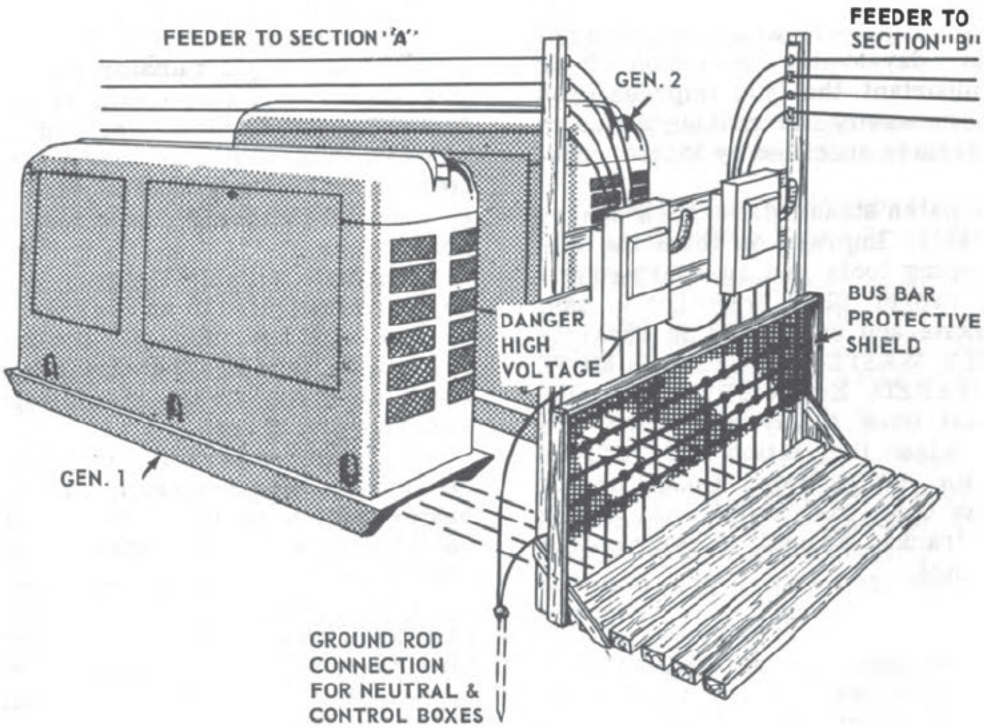

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Figure 6-13.—Typical bus bar installation.

It will be up to you to supplement this information with the specific instructions given in the manufacturer's instruction manuals furnished with each piece of equipment. Similarly, familiarity with the station's electrical system as a whole can be gained only by a study of information relating specifically to that installation. This information can be found to some extent in the manufacturer's instruction manuals but the greater part of it will be obtained from the station's electrical plans and wiring diagrams. Remember, however, that a study of the electrical plans and diagrams must be supplemented with an actual study of the generating station's system itself. In that way the generators, switchgear, cables, and other electrical equipment are not merely symbols on a plan but physical objects whose location is definitely known, and whose functions and relation to the rest of the system are thoroughly understood.

GENERATOR WATCH

When you are in charge of a generating station, you will be responsible for scheduling around-the-clock watches to ensure a continuous and adequate amount of electrical power. Depending on the number of operating personnel available, the watches are evenly divided over the 24-hour period. It is a common practice to schedule 6-hour watches, or they may be stretched to 8-hour watches without working undue hardship on the part of the crew members. Watches exceeding 8 hours, however, should be avoided unless emergency conditions dictate their use.

The duties assigned to the men on generator watches can be grouped into three main categories: (1) operating the equipment, (2) maintaining the equipment and (3) keeping the daily operating log. Operating and maintaining the generating equipment will be covered in succeeding sections of this chapter, so for the present you can concentrate on the importance of the third duty of the station operator—keeping a daily operating log.

The number of operating hours are recorded in the generating station log. The log serves as a basis for determining when a particular piece of electrical equipment is ready for inspection and maintenance. The station log can be used in conjunction with

previous logs to spot gradual changes in equipment condition which ordinarily are difficult to detect in day-to-day operation. It is particularly important that you impress upon your men the necessity for making accurate recordings at periods specified by local operating conditions.

Ensure that watch standers keep their spaces clean and orderly. Impress on them the importance of keeping tools and auxiliary equipment in their proper place when not in use. Store clean waste and oily waste in separate containers. OILY WASTE CONTAINERS MUST BE KEPT COVERED. Empty oily waste containers at least once a day to reduce fire hazards. Care given the station floor will be governed by its composition. Generally, it should be swept down each watch. Any oil or grease that is tracked around the floor should be removed at once.

SWITCHGEAR

Switchgear as you know is a term covering the switching and interrupting devices with their components that control, meter, protect and regulate power equipment. Your inspection and maintenance schedule for the switchgear equipment will be determined for the most part by local operating conditions and the recommendations of the manufacturer. In general, a check and inspection should be made at least once a year. The procedure for maintaining and inspecting switchgear equipment is covered in the Construction Electrician Course 3 and 2 training course.

The operation, maintenance and repair of circuit breakers is covered in chapter 4 of this course.

SINGLE PLANT OPERATION

Connecting an electric plant to a deenergized bus involves two general phases: (1) starting the diesel engine and bringing it up to rated speed under control of the governor and (2) operating the switchboard controls to bring the generator's power onto the bus.

The instructions which follow apply for single operation of the 600-kw generator, described earlier in this chapter. The unit has been grounded, leveled, and properly braced to a suitable foundation.

Proceed as follows:

1. Unfasten all radiator shutter locks; open the two forward side doors of the cab and two forward roof hatches; open the main engine exhaust stack and cable door; remove the cable from cable reel and make necessary connections to the unit receiving power and to two ground connections.
2. Install suitable lightning arresters when service is supplied to an overhead line.
3. Check the lube oil, cooling water, and fuel supply, and see that they are at the proper level; be sure that the air storage tank has a pressure of 150 psi.
4. If cab temperature is below 45° F, start oil-fired cooling system heater by turning the heater switch to ON position, HIGH or LOW as conditions require. Allow heater to operate until main engine temperature reaches 80° F.
5. If specific gravity of storage battery is 1.200 hydrometer reading or lower, the battery charging rectifier must be started, using either outside power source or auxiliary generator for current supply to rectifier.
6. Check control panel for proper changeover link arrangement: delta connection for 2400v or star connection for 4160v.
7. Start air compressor if air pressure in receiving tank is less than 150 psi.
8. Check to make certain the shipping blocks are removed from the voltage regulator, three overcurrent relays, and reverse power relay.
9. If lube oil level in main engine base is low, close the circulating control valve and open the intake valve on lube oil lines under main engine lube oil filter and start lube oil circulating pump. WARNING: Close the intake valve and open the circulating control valve immediately when oil gage in main engine base indicates FULL.
10. Fill auxiliary engine fuel storage tank by closing the fuel control valve, open the fuel intake valve and work hand transfer pump lever back and forth until tank is full.
11. Close the fuel intake valve and open the fuel control valve to prime main engine fuel system. Work hand pump until 25 psi of fuel pressure shows on the engine instrument panel gage.
12. Open the valve on main air supply to main engine air-starting motor.
13. Move ON-OFF switch on engine panel to ON position.

14. Set LOAD LIMIT dial on main engine governor to No. 10 position and the SYNCHRONIZING dial at No. 5 position.

15. Hold down safety control switch, on engine panel, and press starting switch, until engine starts. Continue to hold safety control switch until 30 psi oil pressure shows on engine lube oil pressure gage.

16. Reset annunciator; clear it, if necessary.

17. Check indicating lamps on engine panel to determine that radiator shutters are unlocked; lamps are red if shutters are locked.

18. Check color of indicating lamps on electric panel for proper voltage connection, amber for delta at 2400v and blue for star at 4160v.

19. Adjust field rheostat and voltage regulator to obtain desired voltage.

20. Turn incoming synchronizer to ON position and engage main circuit breaker.

21. Adjust frequency to 60 cycles with governor control switch on electric panel.

22. Place power switch on electric panel to TRANSF for power supply from main engine.

PARALLEL OPERATION

The following is a general guide to the operator when placing two 600-kw units (described earlier in this chapter) in parallel operation. The units should be thoroughly warmed before any attempt is made to place them in parallel. After the units attain proper operating temperatures, you should set the engine speed to 1200 rpm, 60 cycles and then properly adjust the governors. To prevent shifting of this load from one unit to the other during parallel operation, adjust one engine governor with zero droop to maintain frequency. The other unit(s) that are to be placed in parallel on the line load must be set with the proper speed droop to carry the desired portion of the load. The zero-droop engine will absorb all load changes and maintain any frequency for which it is set until it becomes overloaded or until its load is reduced to zero. The droop units will assist in correcting speed changes on large load disturbances but will return to their original loads after the load change has been absorbed by the zero-droop unit.

The following steps must be followed to obtain the above mentioned results:

1. Adjust one engine governor to zero droop with the governor speed droop dial.

2. Adjust additional units to speed droop required to handle desired portion of load (30-50) setting recommended. NOTE: No more than one unit may be adjusted with zero droop when operating in parallel.

3. Place synchronizing switch in ON position and note phase rotation indicated by synchronizing lamps and synchroscope on the electric panel. NOTE: synchronizing lamps will get dark and bright alternately when phase rotation is correct.

4. Change voltage changeover switch to AUTO position and remove all exciter resistance by turning the exciter rheostat slowly to its extreme counterclockwise position.

5. Adjust the voltage of the incoming unit, using the voltage regulator rheostat, to the identical voltage indicated on the bus voltmeter.

6. Adjust the frequency of the incoming unit, using the governor control switch, until the synchroscope hand slows and stops at 12 o'clock.

7. After the circuit breaker of the incoming unit is thrown, check and adjust the load distribution by adjusting the governor speed control switch on the electric panel: FASTER to add load and SLOWER to remove load.

8. Maintain approximately one-half load on the zero droop unit by manually adding or removing the load from the speed-droop units as described in step 7.

9. Repeat the procedure listed in steps 1 through 8 for each additional unit to be paralleled.

After the engines are adjusted as described herein, the units should handle normal load fluctuations without further adjustments provided that the engine governors are adjusted properly.

Emergency Shutdown (600-kw generator)

In the event of engine overspeed, high jacket water temperature, and/or low lubricating oil pressure, the engine may be shutdown and disconnected from the main load by tripping the main circuit breaker. In addition, an alarm will sound to indicate the cause of shutdown. After an emergency shutdown and before the engine is returned to operation, the cause of shutdown should be investigated and corrected. NOTE: It is important to check the safety controls at regular intervals to determine that they are in good working order.

OPERATING RULES AND PRECAUTIONS

The orders that you post in the station for the guidance of the watch standers should include a general list of operating rules and electrical safety precautions. BE SURE YOU ENFORCE THEM!

The important operating rules are relatively few and simple. They are:

1. Watch the switchboard instruments. They show how the system is operating, reveal overloads, improper division of kilowatt load or of reactive current between generators operating in parallel, and other abnormal operating conditions.

2. Keep the frequency and voltage at their correct values.

A variation from either will affect, to some extent at least, the operation of the base's electrical equipment. This is especially true of such equipment as teletypewriters or electric clocks. To maintain reasonably constant frequency, an electric clock and an accurate mechanical clock should be installed together at the powerhouse so that the operators can keep the generators on frequency.

3. USE GOOD JUDGMENT WHEN RECLOSING CIRCUIT BREAKERS AFTER THEY HAVE TRIPPED AUTOMATICALLY. For example, generally the cause should be investigated if the circuit breakers trips immediately after the first reclosure. However, reclosing of the breaker the second time may be warranted if immediate restoration of power is necessary and there was no excessive interrupting disturbance when the breaker tripped. It should be kept in mind however, that repeated closing and tripping may damage the circuit breaker and thus increase the repair or replacement work.

4. Don't start a plant unless all its switches and breakers are open and all external resistance is in the exciter field circuit.

5. Don't operate generators at continuous overload. Record the magnitude and duration of the overload in the log; record any unusual conditions or temperatures observed.

6. Don't continue to operate a machine in which there is vibration until the cause is found and corrected. Record the cause in log.

The electrical safety precautions that should be observed by the station personnel are:

1. Treat every electrical circuit, including those as low as 35 volts, as a potential source of danger.

2. Except in cases of emergency, never allow work on an energized circuit. Take every care to insulate the person performing the work from ground. This may be done by covering any adjacent grounded metal with insulating material such as dry wood, rubber mats, dry canvas, or even with several thicknesses of heavy dry paper. In addition provide ample illumination; covering working metal tool with insulating rubber taps; stationing men at appropriate circuit breakers or switches so that the switchboard can be deenergized immediately in case of emergency; and make available a man qualified to render first aid for electric shock.

REMINDER

Inspection and servicing procedures covered in this chapter are rather general. In most cases they can be applied to any electric power generator that you install. You realize of course, that there are other special installation details which pertain only to the particular generator you happen to be working on. Because of the many different types of generators there are instructions that are applicable to a specific type of generator. Therefore, you should consult the manufacturer's instruction manuals for these details. SAVE THESE INSTRUCTION MANUALS! Additional copies are rarely available.

You must keep in mind that you are responsible for any failure of the generator(s) due to improper servicing and operation by your

crew. It is the small precautions that are overlooked that cause most generators to fail. Are your crew members servicing and inspecting the equipment according to prescribed procedures? Did you instruct your men on proper safety procedures? Are you enforcing these rules? Safety warnings such as keeping the funnel in contact with the fuel tank when filling it with gasoline might save a life and ensure a full working crew.

CHAPTER 7

POWER DISTRIBUTION SYSTEM

A distribution system includes all parts of an electrical system between the power source and the customer's service entrance. The power source may be either a local generating plant or a high-voltage transmission line feeding a substation which reduces the high voltage to a voltage suitable for local distribution. (See fig. 7-1.) The problem of distribution includes the design, construction, operation, and maintenance of a distribution system that will economically supply adequate electric service to the load area. At most advanced bases the source of power will be generators connected directly to the load.

A power distribution system may be either an overhead distribution line or an underground cable system. In most Navy installations, however, the overhead system is used. This chapter will therefore be mainly concerned with the overhead distribution system.

Generally speaking, an overhead distribution system can be installed and maintained more cheaply than an underground system. Also, for equivalent conductor size, an overhead system has higher current capacity and offers greater flexibility with regard to changes in circuits and taps than an underground system. Overhead distribution should normally be used unless climatic or unusual conditions dictate otherwise. In the vicinity of airports or landing strips, for example, it may be necessary to install an underground distribution system.

On most Navy installations and at some advance bases, the primary voltages are 2400/4160 three-phase four-wire 60 cycle systems. The secondary line voltage is normally 120/208 volts, and is supplied to the load through a transformer or transformer banks.

PRIMARY FEEDERS

Primary feeders are those conductors in a distribution system that are connected to the substations and extend to the distribution centers, (See fig. 7-1.) They may be arranged as radial, loop, or network systems.

Radial Distribution System

A typical schematic of a radial distribution system is illustrated in figure 7-2. You will note the independent feeders branch out to several distribution centers without intermediate connections between feeders.

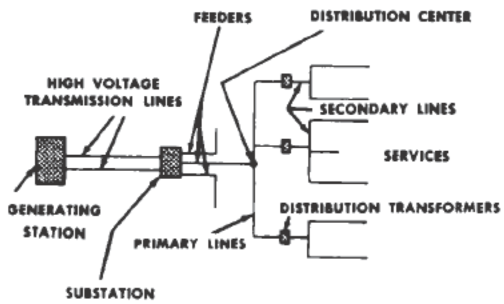
The radial distribution system is the most frequently used system, because it is the simplest and least expensive system to build. It is not as reliable as most systems, however, because a fault in the main feeder may result in an outage on all loads served by the feeder.

The service on this type of feeder can be improved by installing automatic reclosing circuit breakers, which will reclose the service at predetermined intervals. If the fault continues after a predetermined number of closures, the breaker will be locked out until the fault is cleared and service is restored by hand reset.

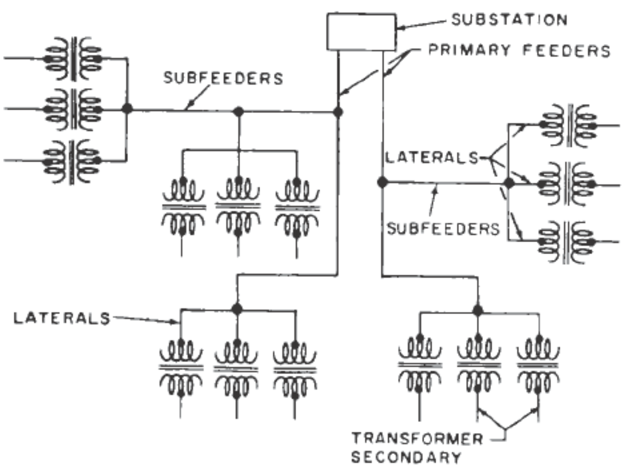
Loop or Ring System

The loop (or ring) system starts at the substation, and is connected to or encircles an area serving one or more distribution transformers or load centers; the conductors of the system return to the same substation.

The loop system (fig. 7-3) is more expensive to build than the radial type, but it provides a more reliable system. It may be justified in an area where continuity of a service is of considerable importance—at a medical center for example.



26.77
Figure 7-1.—A transmission and distribution system.



26.78
Figure 7-2.—Primary radial feeder.

In the loop system, circuit breakers sectionalize the loop on both sides of each distribution transformer connected to the loop. The two primary feeder breakers and the sectionalizing breakers associated with the loop feeder are ordinarily controlled by pilot wire relaying or directional overcurrent relays. Pilot wire relaying is used when there are too many secondary substations to obtain selective timing with directional overcurrent relays.

A fault in the primary loop is cleared by the breakers in the loop nearest the fault, and power is supplied the other way around the loop without interruption, to most of the connected loads. If a fault occurs in a section adjacent to the distribution substation, the entire load may have to be fed from one direction over one side of the loop until repairs are made. Sufficient conductor capacity must be provided in the loop to permit operation without excessive voltage drop or overheating of the feeder when either side of the loop is out of service. If a fault occurs in the distribution transformer, it is cleared by the breaker in the primary leads, and the loop remains intact.

Network System

The network and radial systems differ with respect to the transformer secondaries. In the network system, transformer secondaries are paralleled; in a radial system they are not.

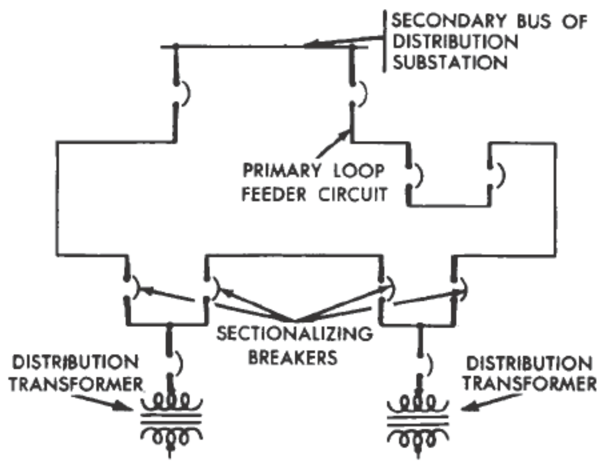
The network is the most flexible type of primary feeder system; it provides the best service reliability to the distribution transformers or load centers, particularly when the system is supplied from two or more distribution substations. Power can flow from any substation to any distribution transformer or load center in the network system. The network system is more flexible with regard to load growth than the radial or loop system and adaptable to any rate of load growth. Service can readily be extended to additional points of usage with relatively small amounts of new construction. The network system, however, requires large quantities of equipment and extensive relaying; it is therefore more expensive than the radial system. From the standpoint of economy, the network system is suitable only in heavy-load-density areas where the load center units range from 1000 to 4000 kva. (See fig. 7-4.)

Primary Selective System

In some instances a higher degree of reliability can be attained with a primary selective system. In such a system, two feeders supply a single load center, with switching arranged for selection of either feeder. This selection may be made manually or automatically.

DISTRIBUTION CENTER

The distribution center (fig. 7-5a and fig. 7-5b) is the location at which the primary main is connected to the feeder circuit. The fused cutout switch for the control and protection



26.79

Figure 7-3.—Primary loop system.

of the primary main is usually mounted on the buckarm below the primary main at the distribution center (fig. 7-6.) The voltage at the distribution center should be maintained practically constant from no load to full load. Constant voltage can be maintained by a feeder voltage regulator at the substation. The voltage can then be held constant at the distribution center by varying the voltage at the substation.

PRIMARY MAINS

The primary mains are connected to the feeder at the distribution load center. They are always located below the feeder on a pole. The primary mains operate at the same voltage as the feeder. The distribution transformers are connected to the primary mains through fused or automatic cutouts. Figure 7-6 shows the primary main to which the transformer is tapped. The cutouts, one on each primary line contain the fuses which protect the transformer against overload and short circuits. The primary mains are strung across the upper crossarm and usually lie in a horizontal plane.

In laying out a distribution system for a base, the base area should be divided into a number of sections. These sections should be chosen so that the loads in each section are close to one of the distribution centers. You do this to keep the length of the mains as short as possible, and to keep the voltage drop low between the distribution and the loads. The distribution or load centers should be located as near as possible to the center of the area of the connected load.

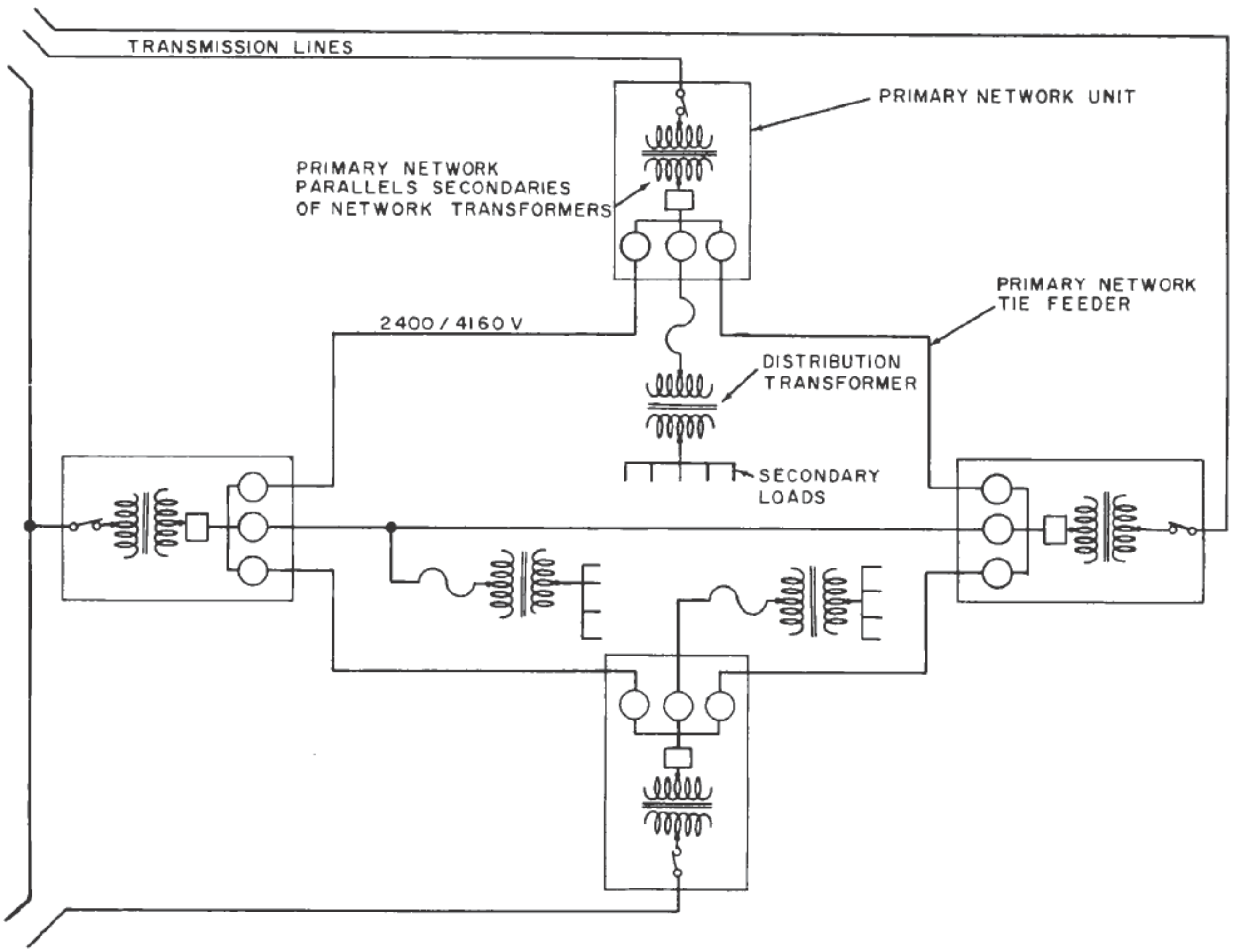
DISTRIBUTION TRANSFORMERS

Most electrical equipment in the Navy utilizes 120/208 volts. The primary voltage distributed on Navy shore installations, however, is usually 2400/4160. A distribution transformer (step down) is therefore, required to reduce the high primary voltage to the utilization voltage of 120/208 volts. The various types of transformer installations are discussed later in the chapter. Regardless of the type of installation or arrangement, transformers must be protected by cutout fuses or circuit breakers, and lightning arresters should be installed between the high voltage line and the fused cutouts.

There are three general types of single-phase distribution transformers. The conventional type required a lightning arrester and fused cutout on the primary phase conductor feeding it. The self-protected (SP) type has a built-in lightning protector; the completely self-protected type (CSP) has both the lightning arrester and the current-over load devices connected to the transformer and requires no separate protective devices.

Transformer Maintenance

Inspection and maintenance of transformers should be scheduled and conducted as outlined in NAVDOCKS P-322 Inspection For Maintenance of Public Works and Public Utilities, Volume one and Inspection Guides—Electrical Volume Two. Maintenance and testing of transformers is covered in NavDocks MO-200 Electrical Power Distribution Systems Maintenance. Any inspection and maintenance of, or in close proximity to, electrical wiring, equipment, or apparatus, is dangerous. All personnel who make such inspections or perform such maintenance must be familiar with, and observe, all the safety precautions set forth in the National Electrical Code, Dept. of the Navy Safety Precautions for Shore Activities, the National Electrical Safety Code, and all the safety rules prescribed by the local command. Electrical accidents, like other types of accidents, do not just happen, but are the direct result of



26.80

Figure 7-4.—Primary network system.

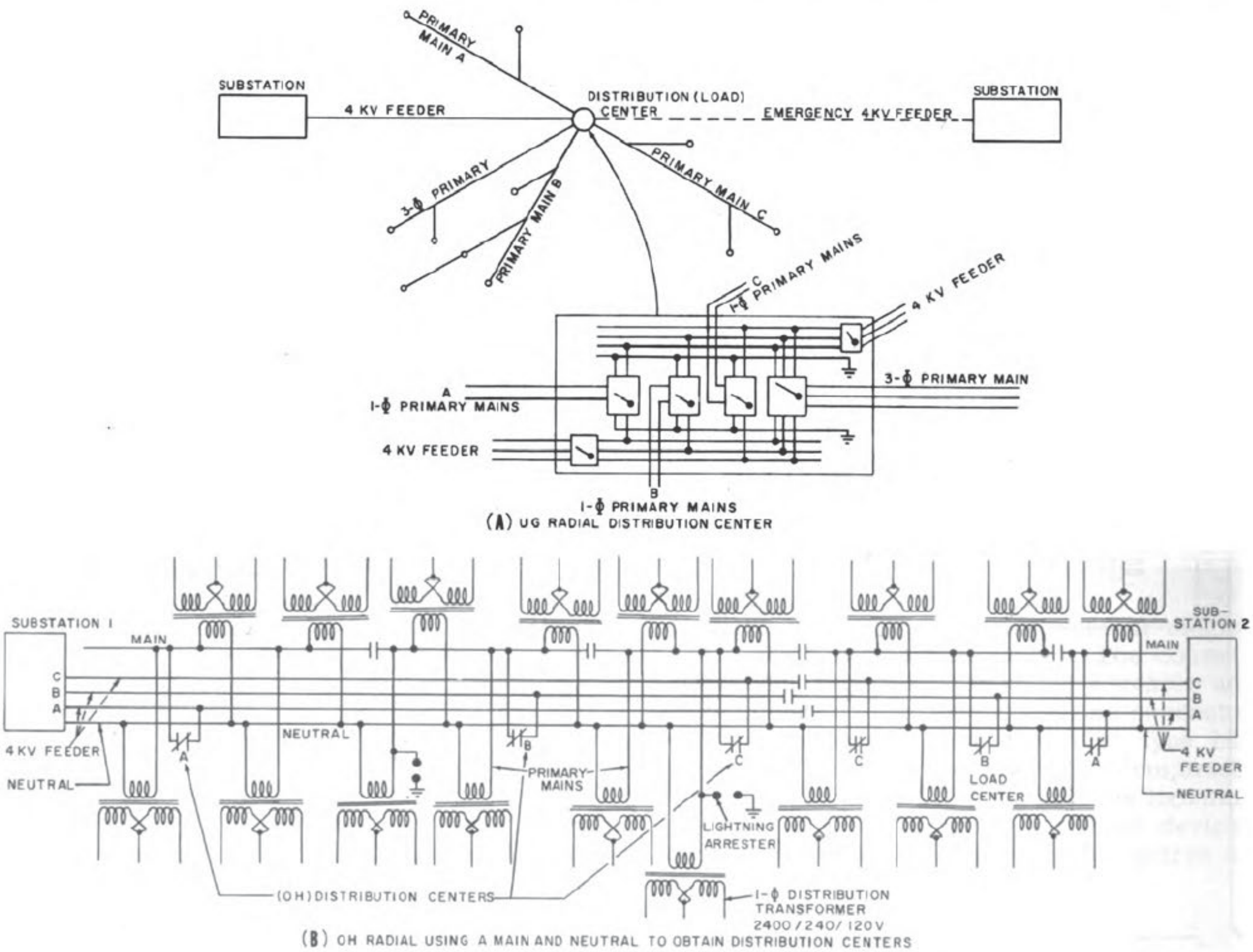
carelessness or failure to observe safety precautions.

CAPACITORS

Another important part of the distribution system is the CAPACITOR. Capacitors are a convenient and practical means to improve the power factor by relieving lines of lagging currents. This action reduces the line current and line losses and improves the line voltage regulation. Capacitors can be installed in relatively small banks and placed on the circuit near the source of reactive lagging kva. Although keeping them on the primary feeders in banks of 45-kva or more is usually more desirable, three phase 15-kva units may be justified in some cases. Normally it is not desirable to improve the power factor above 90 percent, because the capacitive kva per ampere of line current reduction becomes excessive, and is not economical. Size and location of capacitor installations must be approved by the officer acting as electrical superintendent. Typical capacitor installations are shown in figures 7-7 and 7-8.

Listed below are a few rules to help you supervise the installation of capacitors:

1. Use line type lightning arresters on the capacitor banks of the sizes normally used. Large banks require special consideration for proper application of lightning protective equipment.



26.81

Figure 7-5.—(Load) Distribution centers on radial systems (O.H. & U.G.).

2. Use primary cutouts in the majority of installations to connect and disconnect the capacitor bank. A liberal margin between normal current ratings and fuse rating is necessary to avoid unnecessary operation on current transients.

3. Use shunt capability to either increase the load capacity or improve line voltage.

4. Install capacitors at load centers for added load capacity.

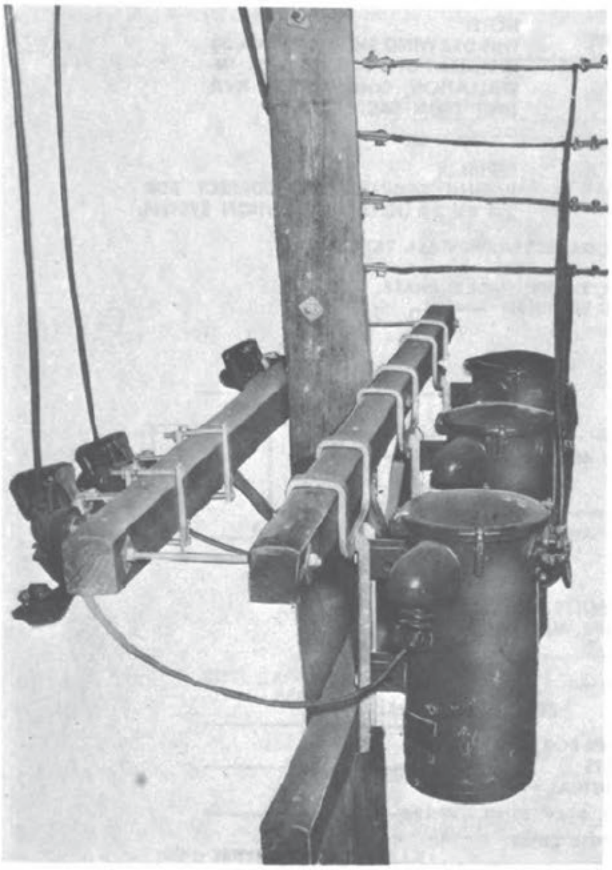
5. Install capacitors at end of line for voltage improvement.

CAUTION: A disconnected capacitor retains its electrical charge for some time, and may have full line voltage across its terminals. A 5-MINUTE WAITING PERIOD MUST BE OBSERVED AFTER THE CAPACITOR IS DISCONNECTED, AND THEN IT SHOULD BE SHORT CIRCUITED AND GROUNDED BEFORE ANY WORK IS DONE ON IT.

SECONDARY MAINS

The secondary distribution system is the last link between the generating station and the individual services. The secondary system includes the range of voltage at which lights, motors and equipment are operated.

Secondary mains can be supported vertically or horizontally. On naval installations, however, they are usually supported vertically on secondary racks or clevises. When a number of services run from each side of the pole, a



26.82
Figure 7-6.—Pole mounted three-phase installation.

secondary rack should be installed on the opposite side (fig. 7-9).

When your crew strings conductors on the secondary, make sure they string all the wire on the same side of the pole. This will make it more convenient to tap service drops. Also, when stringing wire in congested areas, the conductor should be unreeled and passed through the racks or clevises on the poles so that the conductor will not be in the path of any traffic. Where there is no traffic problem, all the conductors can be reeled out on the ground, then raised on to the racks by removing the pin and insulators. This eliminates excessive pole climbing.

After the poles have been properly guyed and the conductors have been dead ended, the conductors are lifted into the grooves of the insulators and tied in. You must remind your crew that on straight lines or inside angles the conductors are placed on the pole side of the insulators; and on the outside angles the conductor is tied in on the outside of the insulator. This is done to keep the strain off the tie wire.

TRANSFORMER CONNECTIONS

The location and size of the transformers are generally determined by standards issued by the Bureau of Yards and Docks, or instructions given by the officer acting as the electrical superintendent. As mentioned earlier, however, you may be called upon to make the decision, and you will be responsible for supervising and instructing your men on the proper procedures for making transformer connections.

SINGLE-PHASE CONNECTIONS

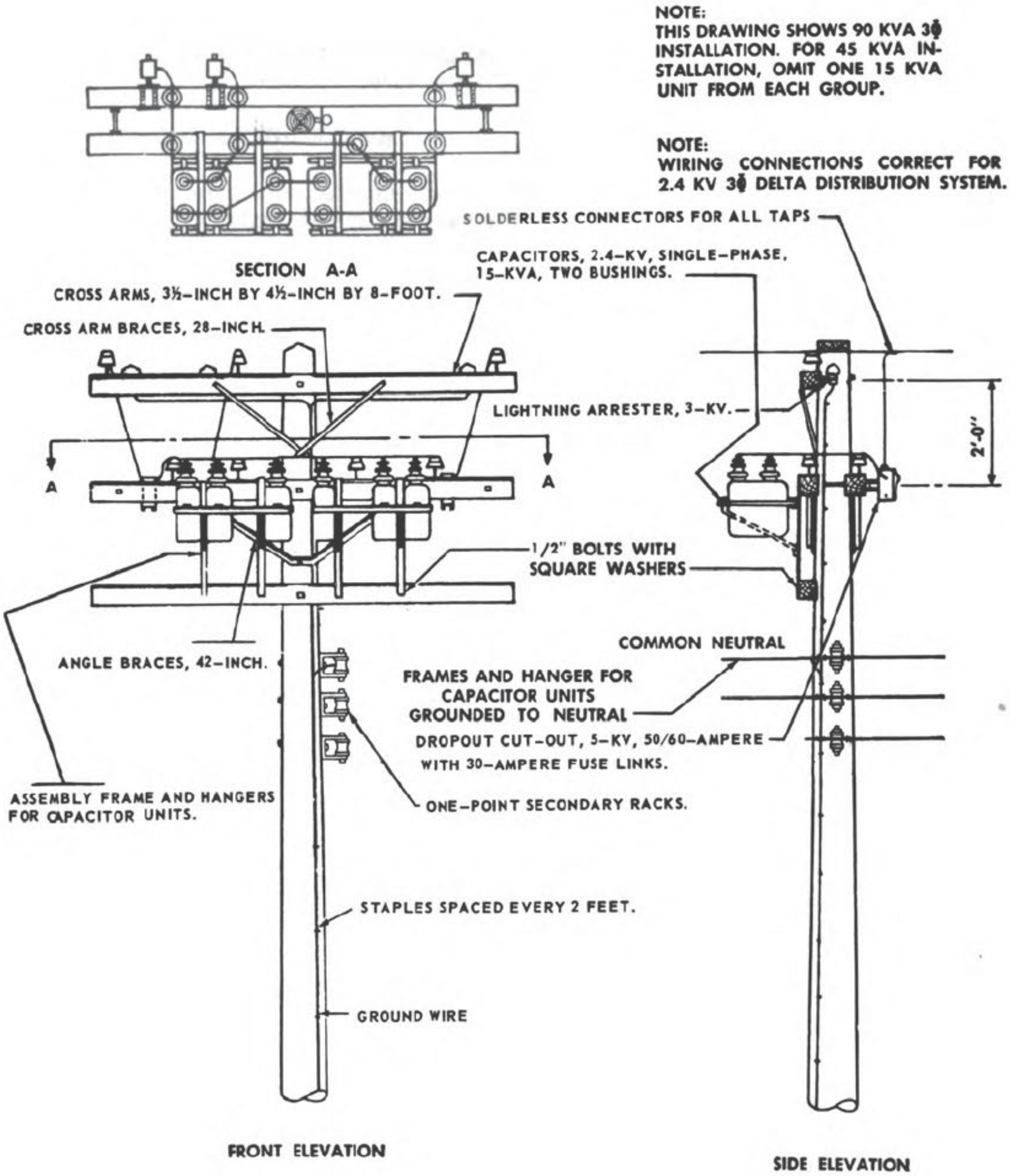
In a single-phase connection the transformer is connected as shown in figure 7-10. The 120/240-volt low voltage wirings are connected in parallel. This type of connection will only supply 120 volts.

The single-phase connection for light and power shown in figure 7-11 is most commonly used on stations using the delta-delta connection for distribution. The three-phase, (three-wire) system makes possible serving both 120-volt and 240-volt loads simultaneously.

Two single-phase transformers can be used parallel on a single-phase two-wire or three-wire secondary system if the terminals with same relative polarity are connected together. This is not an economical operation because individual cost and losses of the smaller transformers are greater than one larger unit giving the same output; it is included as emergency operations for small transformers. In large transformers, however, operating units in parallel is often practical (as in the network system).

DELTA-DELTA CONNECTIONS

The term delta-delta connection in reference to transformers, means that both the primary and the secondary are connected in delta (fig. 7-12). Note X4 of transformer A ties to X1 of B; X4 of B ties to X1 of C; X4 of C ties to X1 of A. This forms a series connection of the three-phases; the sum of the voltage within the delta loop is zero. Always make sure it is zero before closing the loop of the

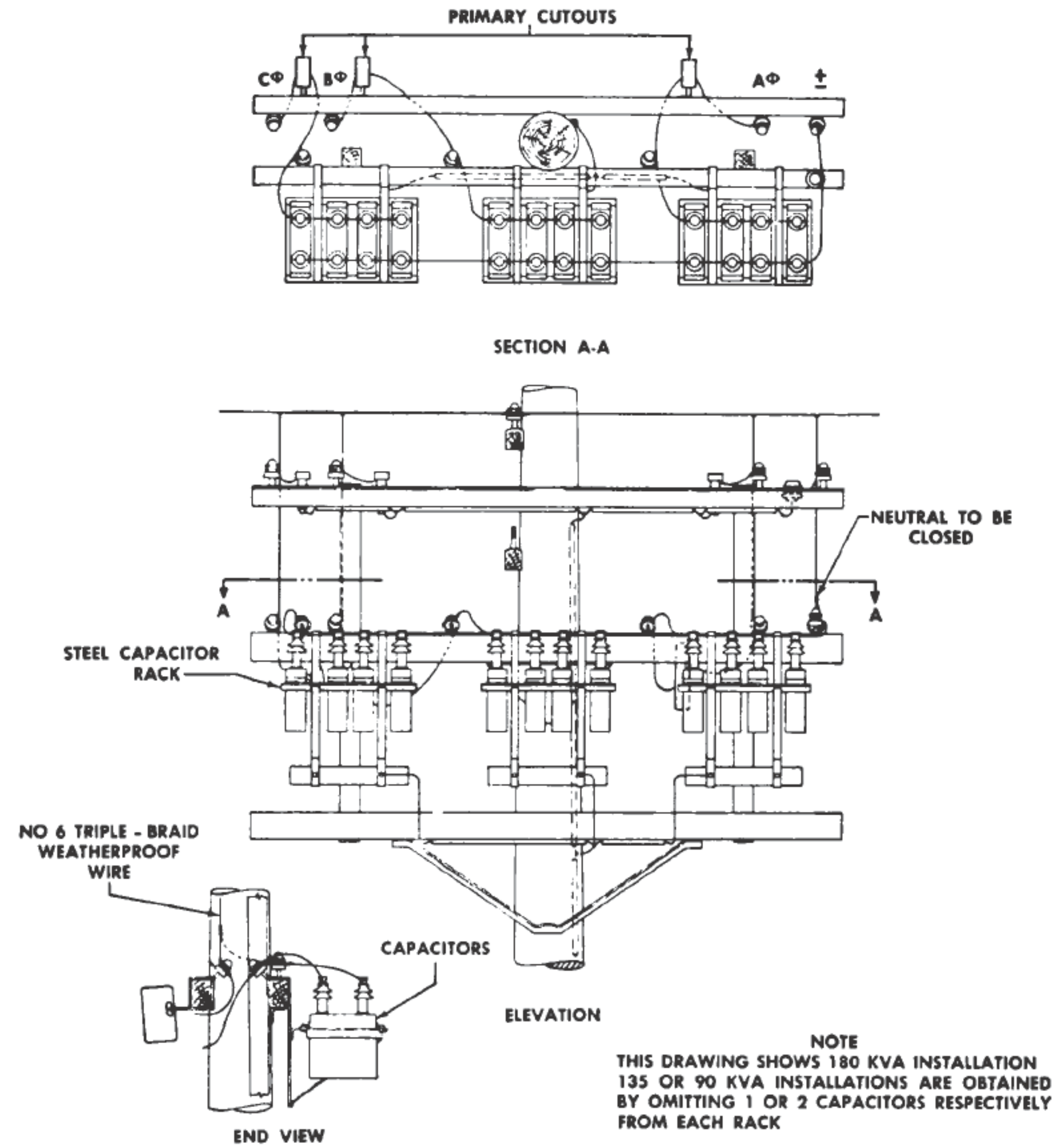


26.83

Figure 7-7.—Capacitor installation on distribution pole, delta primary.

secondary by placing a voltmeter, test lamp, or fuse wire between the two ends of the loop. If the lamp lights, or the fuse wire melts, or any other indications of appreciable voltage exist do not close the loop; if you do, you will short circuit the transformer secondaries. This connection is ideal for service continuity as described later in the open delta connection.

When both light and power are to be supplied from the same bank of transformers, the midtap of the delta secondary of one of the transformers is grounded and connected to the neutral wire of the three-phase secondary system (fig. 7-13). In this case, only one transformer can be used for single-phase loads if the secondaries are to supply three-phase loads



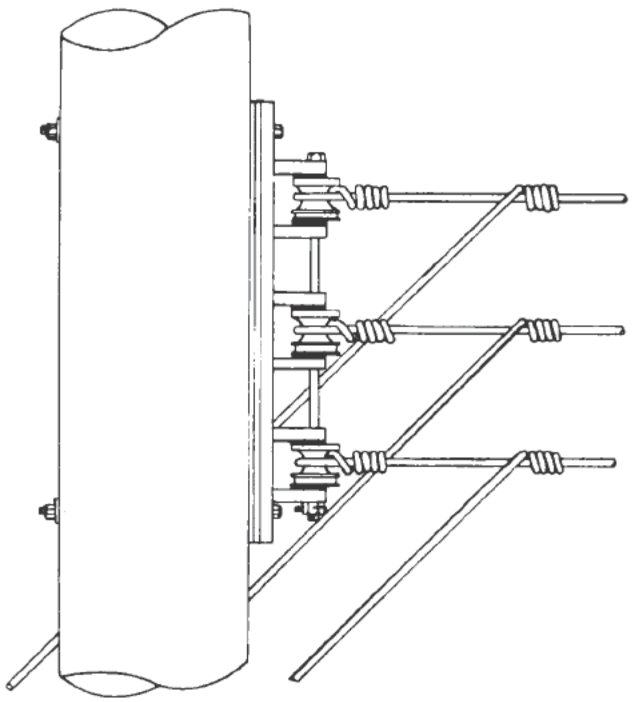
26.84

Figure 7-8.—Typical capacitor installation on distribution pole, four-wire, wye primary.

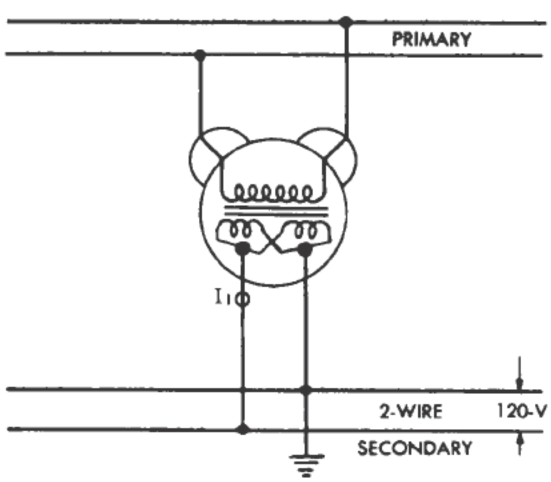
at the same time; because with the neutral of one transformer grounded, (fig. 7-14), a ground on either of the other two transformers at any point would cause a short circuit. The lighting-load is then divided between the two current carrying wires of this same transformer, the grounded wire being common to both branches. The other phase voltage of this three-phase transformer bank is called the "high leg" or "stinger leg" and it must be tagged or identified by some means at all places where it appears with the neutral so that it will not be mistakenly connected with the neutral to form a 120 volt circuit. The stinger leg voltage may be figured by the following formula:

$$\text{stinger leg voltage} = \frac{\sqrt{3}}{2}(240) = 208 \text{ volts}$$

The formula shows that damage could be caused to light bulbs, and equipment if it was mistakenly connected to a 120 volt circuit. Closed-delta is used where the power load is more than 60 percent of the total load on the bank.



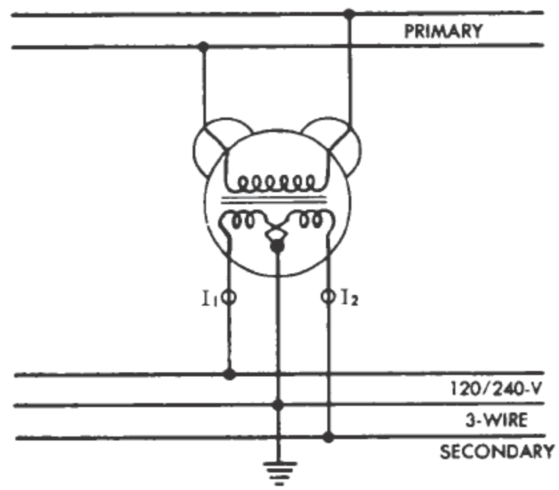
26.85
Figure 7-9.—Attaching open wire service to pole.



26.86
Figure 7-10.—Single-phase connections for small lighting loads.

OPEN-DELTA CONNECTION (POWER)

An open-delta connection for power can be used in an emergency if one of the transformers in a delta-delta bank fails. This type of bank is also used to supply power to a three-phase load which is temporarily light but



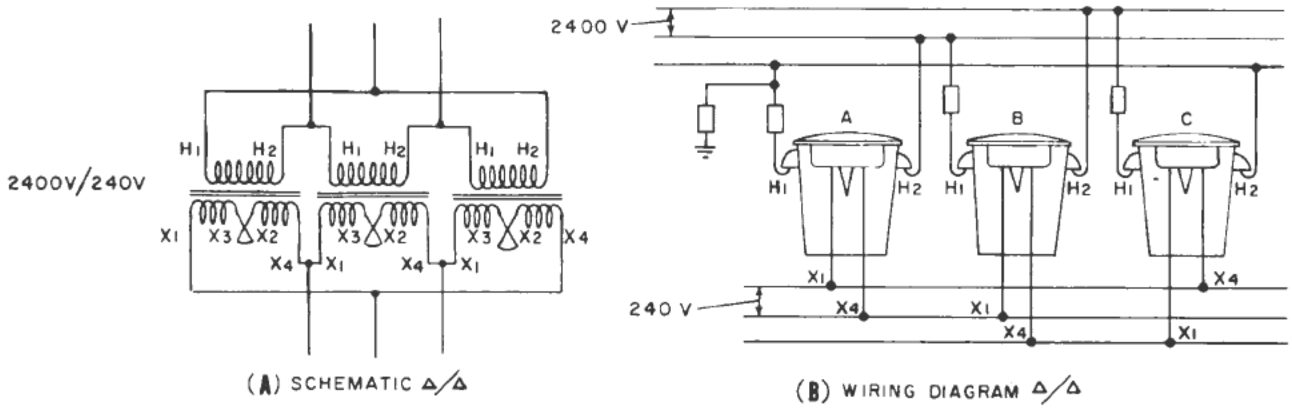
26.87
Figure 7-11.—Single-phase connections for light and power.

which is expected to grow. When the load increases to a point where the two transformers in the bank are overloaded, an increase in capacity of 1.73 times the open-delta bank can be obtained by adding another unit of the same size and using the delta-delta connection. The capacity of an open-delta bank is only 57.7 percent of a delta-delta (closed) bank of the same size units. Three 25-kva transformers connected delta-delta would have a three-phase capacity of 75-kva; two 25-kva transformers in an open-delta bank would have a three-phase capacity of only 43.3 kva (75 X 57.7). In an open-delta bank only 86.6 percent of the rated capacity of the two transformers making up the three-phase bank is realized.

When the secondary circuits are to supply both light and power, the open-delta bank is connected as shown in figure 7-15. In addition to the applications mentioned in the preceding paragraph, this type of bank is used where a large single-phase load and only a small three-phase load occurs. In this case, the two-transformers would have different kva sizes, but the same impedance, the one across which the lighting load is connected being the larger.

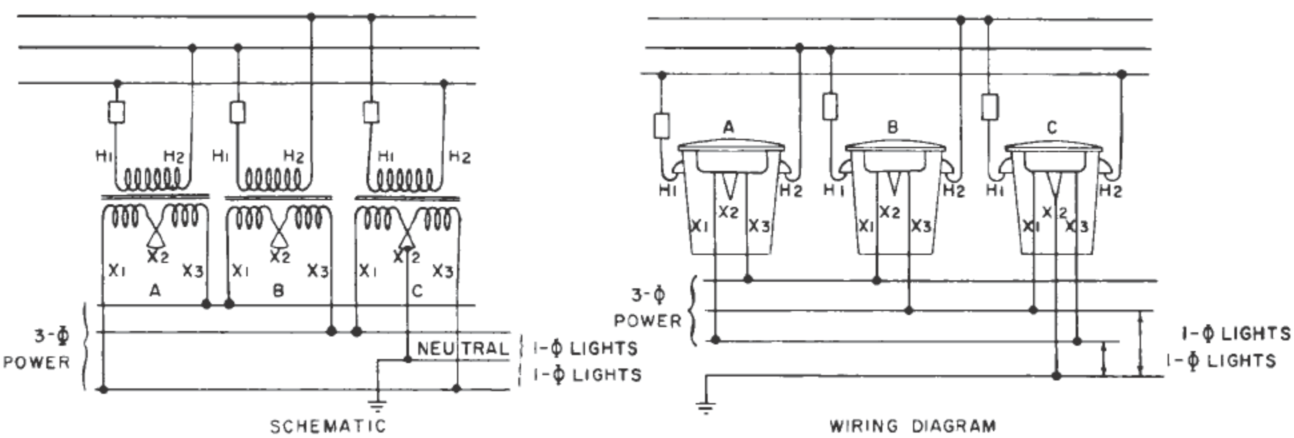
WYE-DELTA CONNECTIONS

The wye-delta connection (fig. 7-16) is used for light and power where more than 60 percent



26.88

Figure 7-12.—Delta-Delta transformer connection for three-phase three wire power.



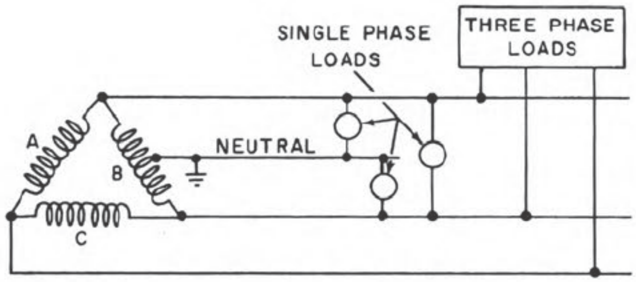
26.89

Figure 7-13.—Delta-Delta connections for light and power.

of the total is power load. If one unit of a wye-delta bank goes bad, service can be maintained by the connection shown in figure 7-17. In regular wye-delta bank with three units, the neutral of the primaries of the transformers is not ordinarily tied with the neutral of the primary system. This bank can be used even when the primary neutral is not available. In the bank with two units, however, the neutral must be connected as shown in figure 7-17. The main disadvantage of this hook-up is that full-load current flows in the neutral even though the three-phase load may be balanced. In addition to maintaining service in an emergency, this type of bank is satisfactory where the main part of the load is lighting and the three-phase load is small.

DELTA-WYE CONNECTION

In all banks mentioned in the preceding paragraphs for serving light and power on the secondary, the grounded secondary wire is not the neutral of the three-phase system, but rather the midpoint of one leg of the delta. Furthermore, all the lighting load is put on one phase; therefore, the primary currents in any one bank are unbalanced. In the delta-wye connection (fig. 7-18), the neutral of the three-phase secondary system is grounded. The single-phase loads are connected between the different phase wires and neutral while the three-phase power loads are connected to the three-phase wires. Thus, 120 volts are supplied to the lighting loads and 208 volts to the power load. With this type



26.90
Figure 7-14.—Three-phase, four wire secondary mains.

of bank the single-phase load can be balanced on the three phases in each bank by itself, and the secondaries of different banks can be tied together.

WYE-WYE CONNECTIONS (LIGHT AND POWER)

The primaries of the transformers can also have a wye connection. When the primary system voltage is 2400/4160 wye, 2400-volt transformers would be used in place of 4160-volt transformers that would be required for the delta-wye connection. A saving in transformer cost results. The primary neutral should be available when the wye-wye connection (fig. 7-19) is used, and the neutrals of the primary and secondary systems and of the bank must be tied together. If the three-phase load is unbalanced, part of the load current flows in the primary neutral. Also the third harmonic component (distorted sine waves) of the transformer exciting current flows in the primary neutral. For these reasons, the neutrals must be tied together, otherwise the line to neutral voltage on the secondary would be very unstable. That is, if the load on one phase were heavier than on the other two, the voltage on this phase would drop excessively and the voltage on the other two phases would rise. Also, larger third harmonic voltages would appear between lines and neutral, both in the transformers, and in the secondary system, in addition to the 60-cycle component of voltage. For a given value of root-mean-square (rms) voltage, the peak voltage would be much higher than for a pure 60-cycle voltage, and would overstress the insulation both in the transformers and in all apparatus connected to the secondaries.

BOOSTER CONNECTIONS

Booster transformers are used to raise or lower the voltage of the circuit from which the

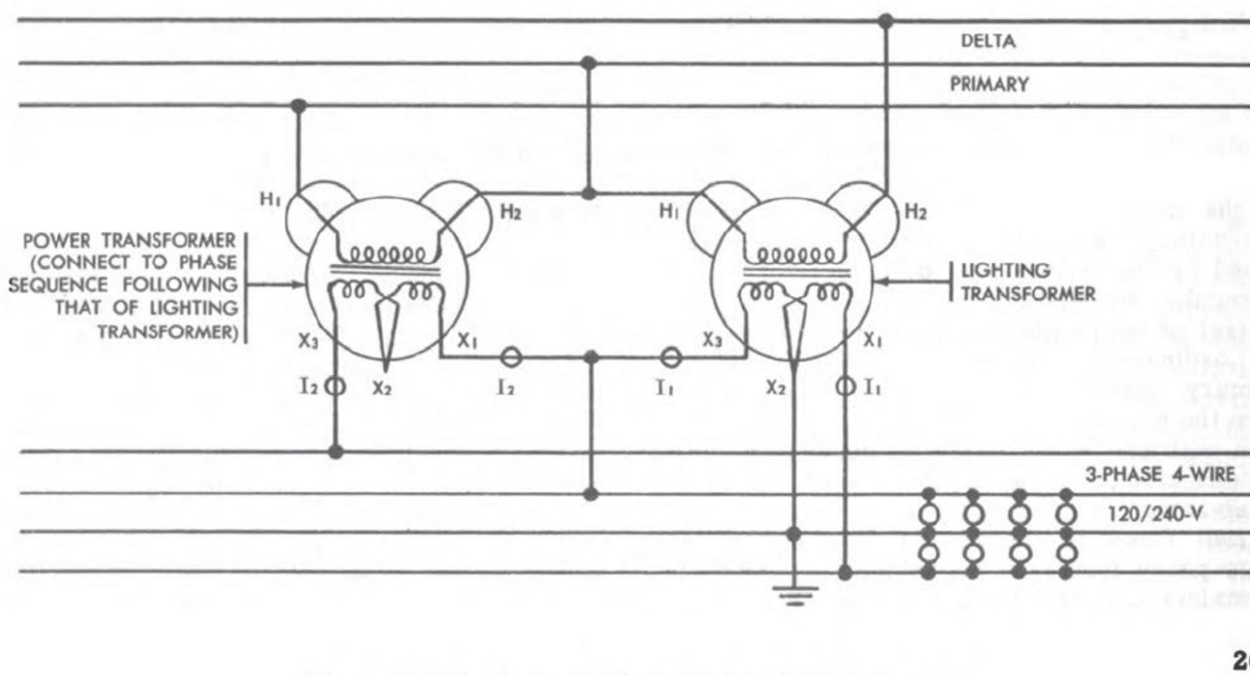


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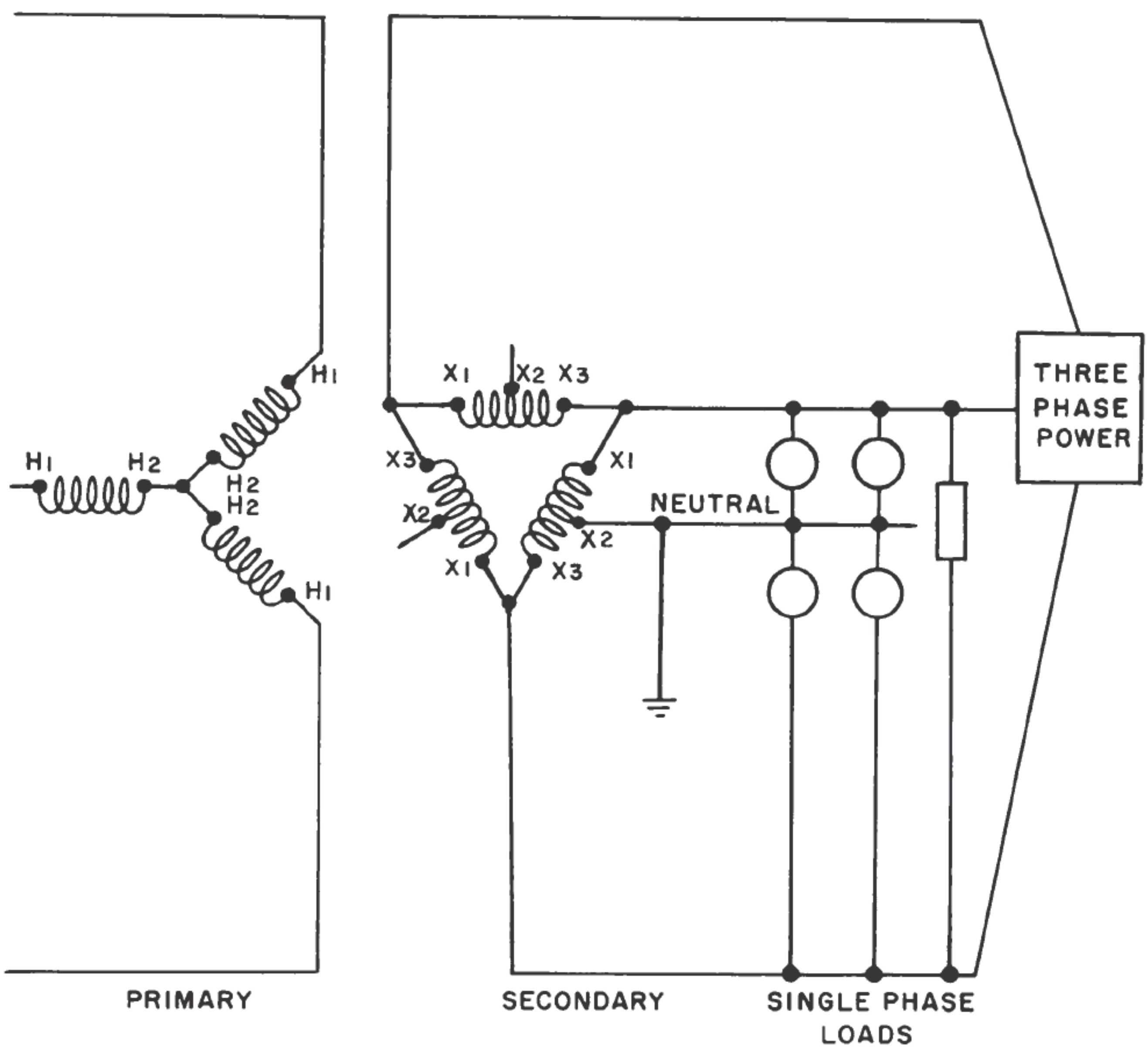
Figure 7-15.—Open-Delta bank for light and power.



26.92

Figure 7-16.—Wye-Delta transformer connections.

transformer is excited. The primary winding is connected in parallel with the line, and the secondary winding is connected in series with the line. By reversing the secondary connection, its action can be changed from boosting to bucking. The secondary voltage is either added to or subtracted from the primary voltage. The low-voltage winding is subjected to the stresses associated with the high-voltage circuit; these stresses must be taken into consideration when using this connection. A booster installation is shown in figure 7-20.

The percentage of voltage change with the booster connection depends on the ratio of the

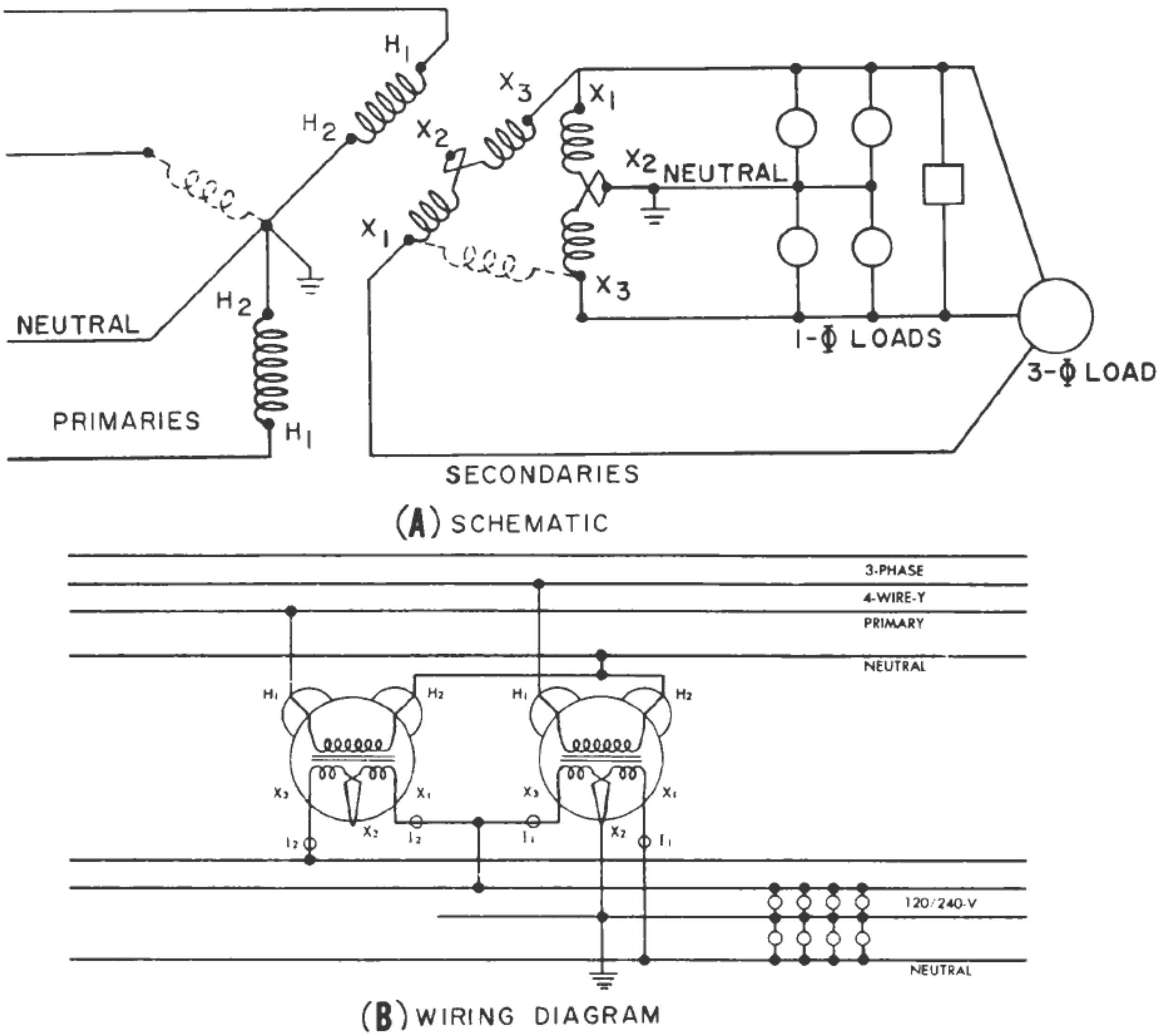


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Figure 7-17.—Wye-Delta connection for 120/240 volt, single phase light and 240 volt, three phase power with one unit missing.

primary to secondary voltage of the transformer. For example, with a 2400-120/240-volt transformer, using the 240-volt secondary, the ratio is 10 to 1 and the secondary voltage is 10 percent of the primary. With the 120-volt secondary, the ratio is 20 to 1, and the secondary voltage is 5 percent of the primary.

A disadvantage of the booster transformer is that it boosts voltages during the periods of light load; this may result in a primary voltage which is too high during certain times of the day. If the connection of a booster transformer lowers the voltage, primary leads are reversed and must be interchanged.

A few suggestions and precautions with respect to booster installations are listed below:

1. When a booster or buck transformer is being disconnected from the circuit, the lead from the secondary winding should be opened first in order to avoid excessive voltage surge.

2. Special booster transformers are available with high-voltage bushings and insulation of the secondary side and are preferred to ordinary distribution transformers for boosting voltage.

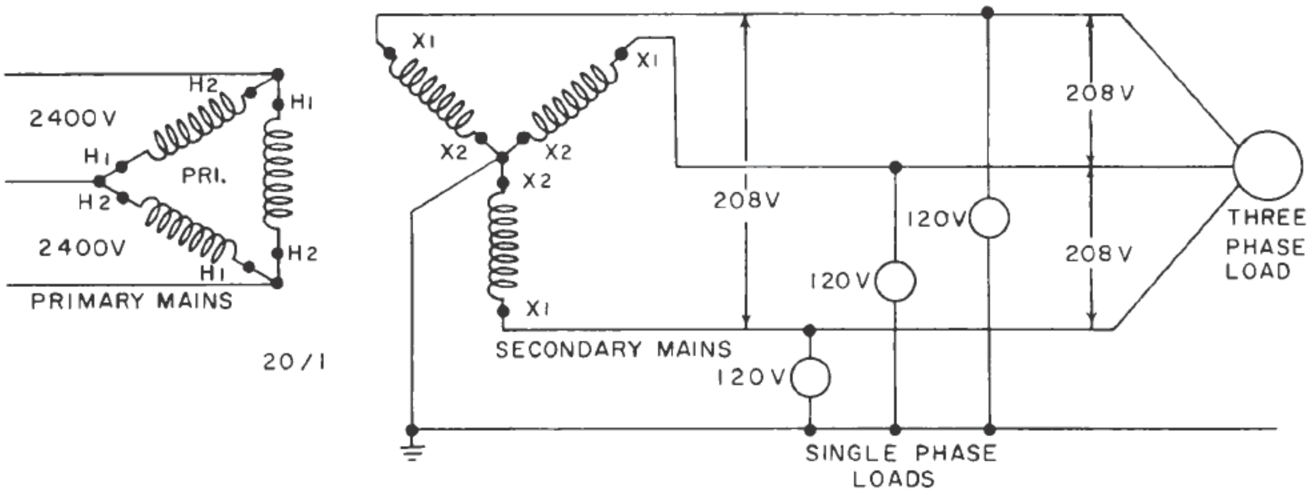

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Figure 7-18.—Delta-Wye connections.

3. Booster connections are not recommended for extensive use on station distribution systems because the secondary winding insulation is stressed by the primary voltage. Such an installation is sometimes the only economical solution for a voltage-control problem or when a temporary connection is necessary until a permanent rearrangement can be made.

T CONNECTIONS

Normally the T connection is not used. However, if you are required to use two transformers to provide three-phase power from a three-phase line the T connection illustrated in figure 7-21 can be used. In making this connection note that both windings of one transformer have 50 percent taps, and the other transformer has 86.6 percent taps on both windings.

SCOTT CONNECTIONS

A Scott connection is used to transform two-phase to three-phase power or vice versa. Two transformers are used, a main transformer and a (teaser) transformer. The main transformer has a 50 percent tap on the three-phase side and the teaser transformer has an 86.6 percent tap on the three-phase side (fig. 7-22). The windings are designed so that the three-phase side will carry the full value of three-phase line current; and the two-phase side windings are designed to carry the full value of two-phase line current.

TRANSFORMER INSTALLATION REQUIREMENTS

When a transformer is to be installed it will be up to you to see that the job is done right. That means you should be up to date on the rules and requirements of the electrical code. The code books that cover various electrical requirements are listed in chapter 1. Study the code requirements carefully before installing a transformer. Some of the particularly important transformer installation rules are listed below.

1. One or more transformers may be hung on a single pole if the total weight does not exceed the safe strength of the pole, or crossarms and bolts supporting them.

2. When more than one transformer is installed on crossarms, the weight should be distributed equally on the two sides of the pole.

3. Single-phase transformers of 50 kva or smaller are usually placed ABOVE the secondary mains if conditions permit. Those larger than 50 kva are usually placed BELOW the secondary mains.

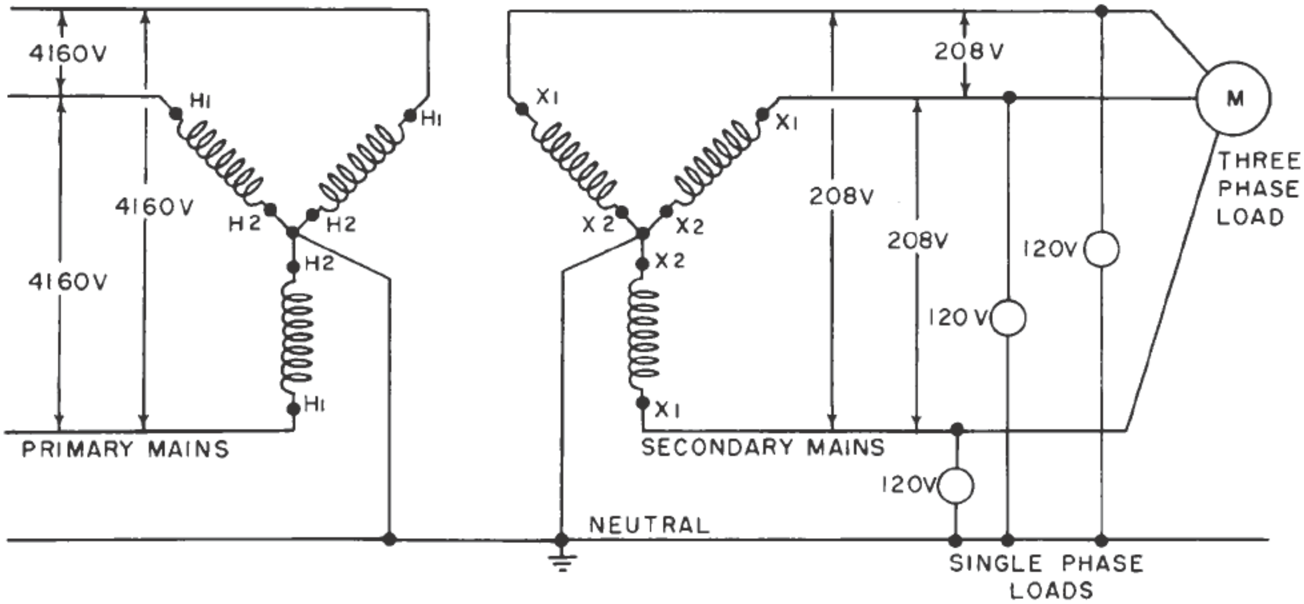

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Figure 7-19.—Wye-Wye connections.

4. Lightning arresters and fused outouts must be installed on the primary side of all distribution transformers except the self-protected type.

5. Ground wires must be covered with a wood moulding to a point 8 feet above the base of the pole.

The rating (size) of the fuse link used in primary cutout is also important. The chart in figure 7-23.

Table 7-1.—Proper size secondary training wire for transformer

Transformer size (kv.-a.)	Size of outside secondary leads	Size of central or neutral lead
20 or smaller......	6	6
25 or 30	4	6
37 1/2 to 50	0	0
75	4/0	0
100.............	350 MCM	4/0
125.............	500 MCM	4/0
150 or 200	750 MCM	350 MCM

will help you pick the correct fuse size. As an example, suppose you have installed a single-phase 75-kva transformer that operates from a 2400 volt primary. Using the chart, first find the transformer capacity (75) on the left side of the chart. Then proceed horizontally to the right until you intersect the primary voltage line (2400 volts). The point of intersection lies in the 100-ampere fuse-link area. Therefore, for this particular installation you would use a 100-ampere fuse.

The size of the training (connecting) wires used to make the connections between the transformer bushings and the primary and secondary mains is also an important consideration. In general, number 6 weatherproof insulated copper wire or equivalent, will prove satisfactory as training wire for the primary connections of transformers, in size up to 200 kva. The size of the secondary training wire, however, will vary with the size of the transformer as shown in table 7-1. In all cases, the secondary training wire should be weatherproof.

THREE-PHASE TRANSFORMER BANKS

The total amount of power that can be supplied from three single-phase transformers connected

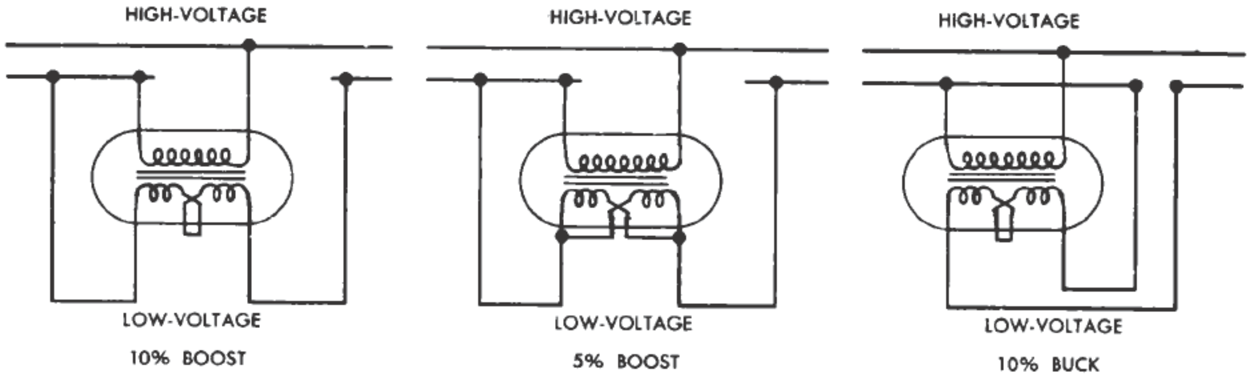

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Figure 7-20.—Booster connections.

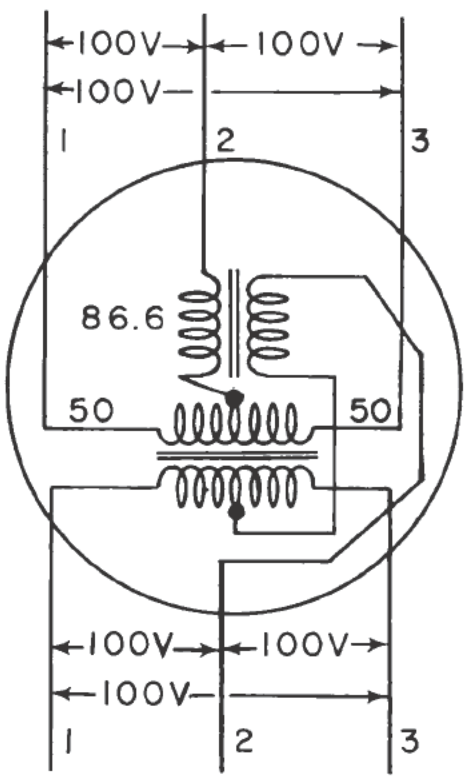

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Figure 7-21.—T connection, three-phase to two-phase.

in a three-phase bank is the sum of each transformers kva capacity. Three 25-kva transformers, for example, can be expected to supply 75 kva of power under stated cooling conditions, provided the transformers are approximately equally loaded.

The protective requirements of a three-phase transformer installation are the same as those of a single-phase service. That is, a lightning arrester and fused-cutout are connected to each phase wire of the primary main feeding the transformer. The size of the fuse, again, is determined by the total capacity of the transformer bank and the value of the primary voltage. The chart in figure 7-24 will help you select the proper size fuse.

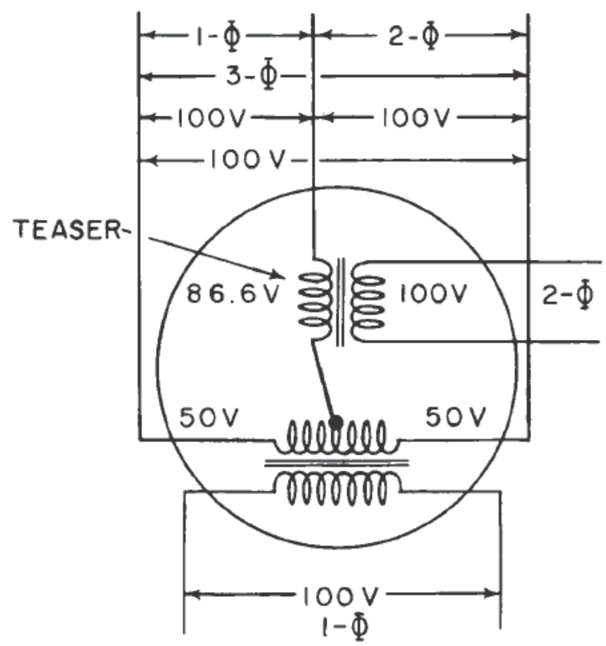

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Figure 7-22.—Scott connection, three-phase to two-phase.

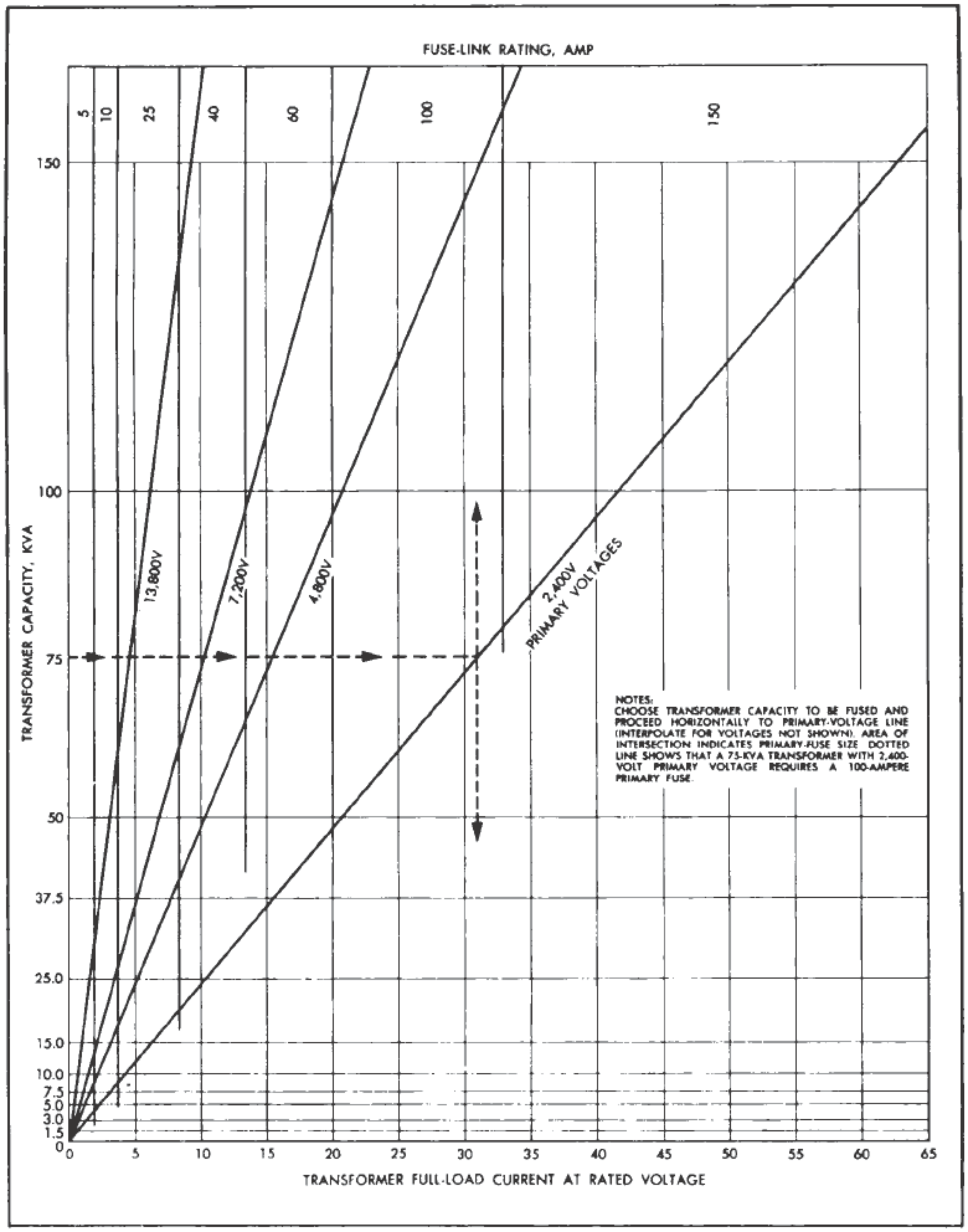

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Figure 7-23.—Fuse size for single-phase installation.

Pole Installation

Three single-phase transformers may be mounted on a single pole for a three-phase installation. The transformers can be secured directly to the pole if equipped with mounting lugs (pole brackets) or hung on a double cross-arm if equipped with hangers.

Figure 7-25 gives an overall view of a typical three-phase installation using three single-phase transformers. The construction features of this installation are typical of those found in other three-phase services mounted on one pole. Notice the method of supporting the transformers. The main support consists of double crossarm mounted approximately 4 feet below

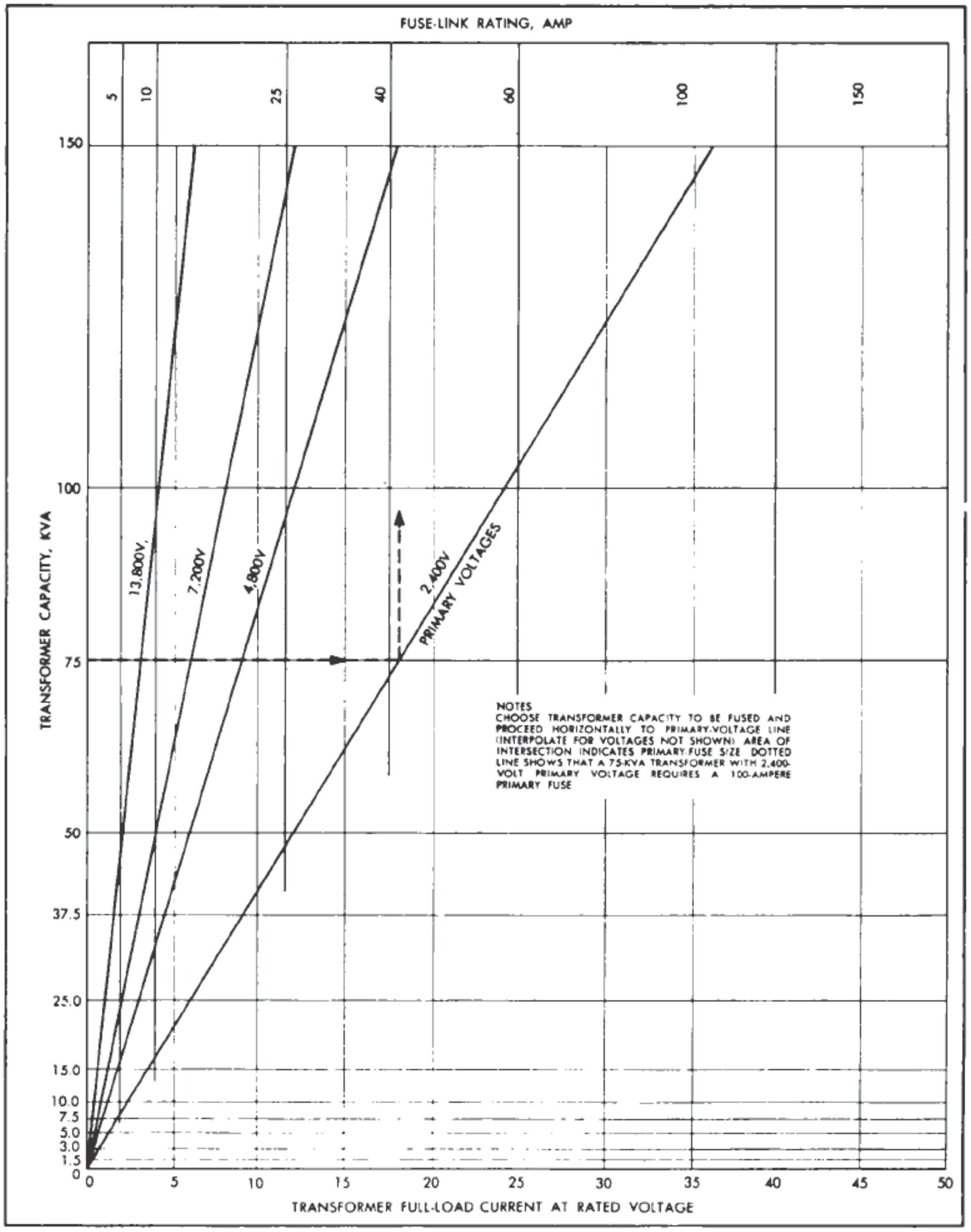

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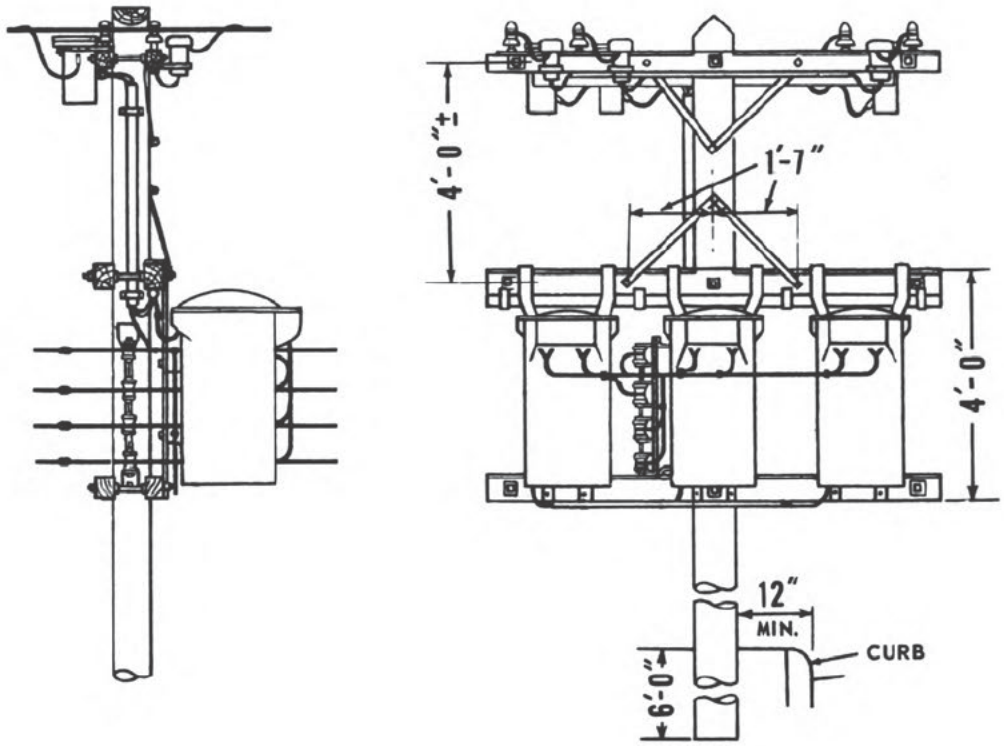
Figure 7-24.—Fuse size for three-phase installation.

the primary main. Notice that a kicker-arm is installed just below the double crossarm. The kicker arm provides a support for the bottom of the transformer hanger and thus maintains the transformer in a rigid vertical position.

Figure 7-26 shows a closeup of lightning arrester connections and mounting. Although only two arresters are visible, there is another mounted on the other end of the crossarm and connected to the third phase of the line. The arresters are clamped in a hanger mounted flat against the side of the crossarm that supports the primary main. A wire from the top of each arrester is connected by means of



26.192

Figure 7-25.—Three phase transformer bank mounted on crossarms.

a solderless connector to a phase wire. Notice the drip-loop in the wire. A ground wire leads from the bottom of each arrester and connects to the main ground wire that is stapled to the underside of the crossarm.

Figures 7-6 and 7-27 show how the primary fuse cutouts are mounted on the double crossarm by means of a cutout hanger. The fuses shown are a combination of disconnect switch and fuse. When the hinged cover is pulled down in the position shown, the training wire circuit leading to the primary bushing is opened. When the hinged cover is closed, the fuse is automatically inserted in the circuit.

Platform Installation

When the combined weight of the transformers cannot be safely handled by one pole, you should have the transformers placed on a platform supported between two poles. Except for the difference in construction, the general principles of connecting the transformers and the protective equipment requirements apply equally to this type installation and to the pole-mounted type.

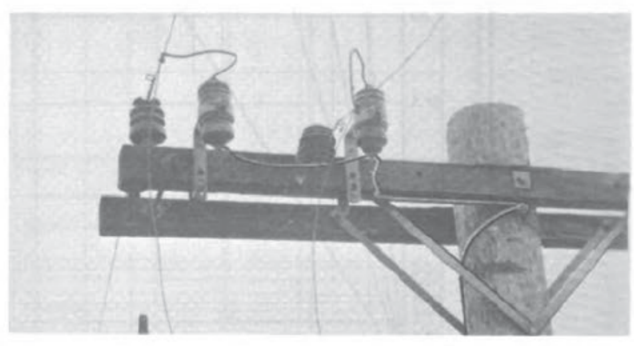


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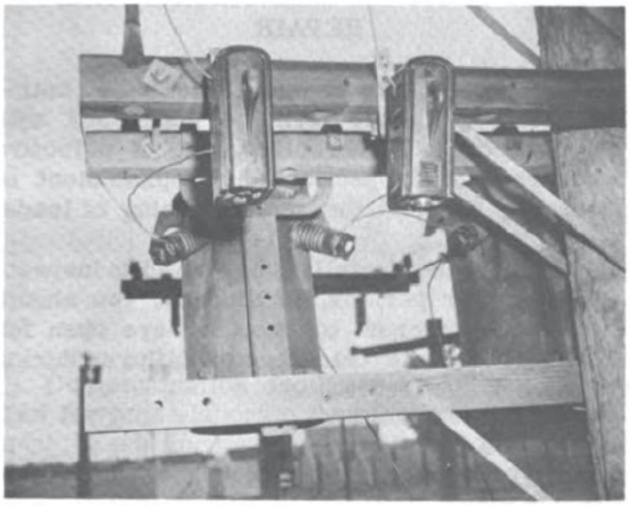
Figure 7-26.—Lightning arrester connections.

The three-phase transformer bank illustrated in figure 7-28 is a typical example of a platform-mounted installation. Both a front and side view are shown and the physical dimensions and electrical requirements are indicated. The platform's foundation is built of two 4-inch by 8-inch creosoted timbers mounted between the poles and bolted on each end to a pair of 4- by 8-inch creosoted crossarms. Two by fours, spaced 1 inch apart, serve as

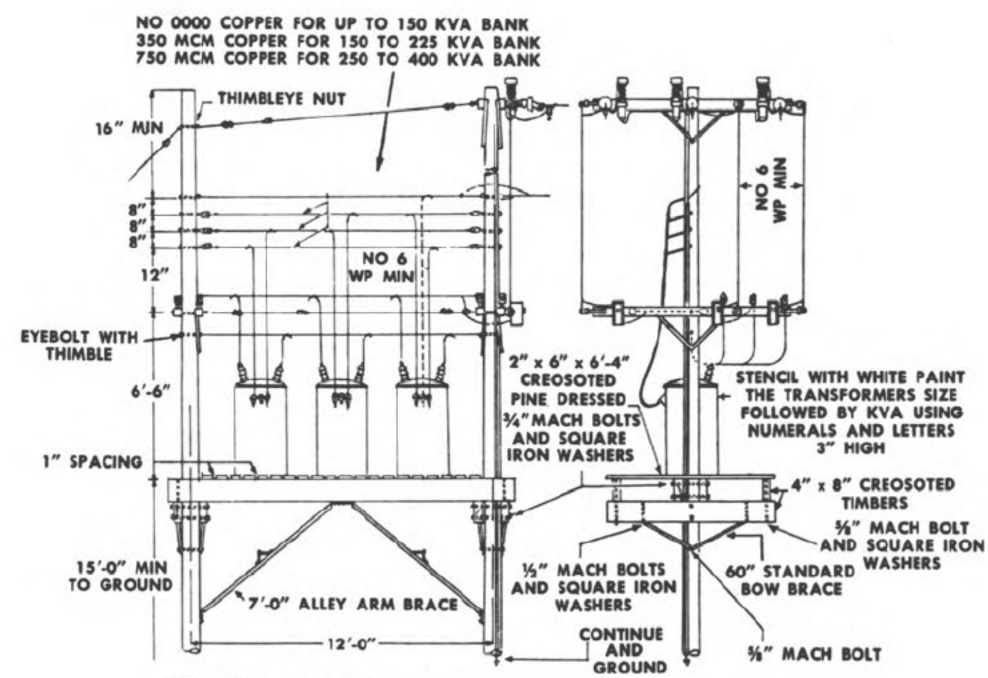


26.102
Figure 7-27.—Primary fuse cutout connections.

weight will be great enough to keep them in place.

In the installation shown in figure 7-28 the transformer bank is placed at the end of the primary main run. Therefore, it is necessary to use a pole-to-pole guy and pole-to-ground guy to counteract the pull of the wires. The three lightning arresters clamped to the top crossarm are connected to the primary main and to a ground wire on the side of the pole. Training wires tapped to each primary main drop down and connect through fuse cutouts to a three-wire primary bus stretched between poles. The secondary bus is also mounted between the poles but above the primary bus.

The transformer bank is connected with a delta primary and a delta secondary. A four-wire secondary main for light and power is obtained by mid-tapping the secondary of one of the transformers.



Note. Three transformers may be from 25 to 100 KVA. Delta Secondary.

26.103

Figure 7-28.—Platform mounted three-phase transformer bank.

the floor of the platform. There will be occasions when the dimensions of the timber which you need cannot always be met by the stock you have on hand. But they should be matched as closely as possible. It is not necessary to bolt the transformers to the platform; their

Ground Installation (Bank)

The larger single-phase transformers when connected into a three-phase bank must be directly on the ground. This situation will arise in some substation installations. You may also find

it necessary to install transformers on the ground if two three-phase banks are needed to supply power to the same area or building. Aside from the special construction features necessary to mount a transformer on the ground, there are only two major safety requirements which make a ground bank installation different from a pole or platform mounted bank. First, in addition to the normal grounding of neutral wires and lightning arresters, all equipment and steel work must be effectively and permanently grounded. Second, a protective fence must be built around the installation with warning signs prominently displayed.

TRANSFORMER MAINTENANCE AND REPAIR

The largest part of your transformer maintenance and repair will be concerned with the inspection and replacement of defective bushings, the inspection and replacement of insulating oil, and the reconditioning of leads.

Transformer installations should be inspected at regular periods. In addition, you should instruct your crew to keep an eye open for any indications of transformer failures during daily work routine.

CHAPTER 8

COMMUNICATION

Communication facilities at advance bases are far less elaborate than facilities at permanent bases located in the United States. The equipment is rugged and as compact and portable as possible.

The most common type of telephone equipment used at advance bases includes the SB-22/PT switchboard, telephone central office set TC-2, TC-4, TC-10, and the AN/TTC-7. Other communication equipment normally found at advance bases are interoffice communication equipment, and public address systems.

As the Construction Electrician First Class or Chief, it is your responsibility to see that the above mentioned communication equipment is properly installed and maintained.

SB-22/PT SWITCHBOARD

The SB-22/PT, is a 12-line, portable, local-battery switchboard. It is designed to establish a working telephone system for units up to and including the size of a battalion. The front and rear view of the 12-line switchboard is shown in figure 8-1A and B.

The SB-22/PT is a small, lightweight, immersion-proof switchboard used for interconnecting local-battery lines. It requires no special mounting equipment for operation. The names of the main parts are given in figure 8-1A and B. The components which comprise the SB-22/PT are shown in figure 8-2.

The SB-22/PT switchboard is also equipped for remote control radio communication. Under normal conditions your crew needs to be concerned only with the telephone lines. The procedure for connecting the wires of the switchboard to a radio circuit is very similar to the procedure for making connections to the telephone circuit.

LINE PACKS

The 12-line packs are located on the left side of the front panel. A line pack is shown in figure 8-3. Each line pack is fastened to the switchboard by two captive screws, one at the top of the unit, the other at the bottom. The line pack consists of a reel unit, a drop, a jack, and an identification strip.

The REEL UNIT consists of a reel, a cord, and a plug. The cord is fastened to the spring-loaded reel by three screws at one end and is equipped with a standard switchboard plug at the other end. The cord may be extended to a maximum distance of 35 inches and is retracted by the spring-loaded reel.

The DROP consists of an electromagnet and a hemispherical piece of metal with a luminous strip painted horizontally across it. When a telephone user turns the crank of the hand generator serving the telephone, a circuit is completed, causing the hemispherical piece to rotate downward; this exposes the luminous strip. The drop is restored by a mechanical linkage between the drop and the jack.

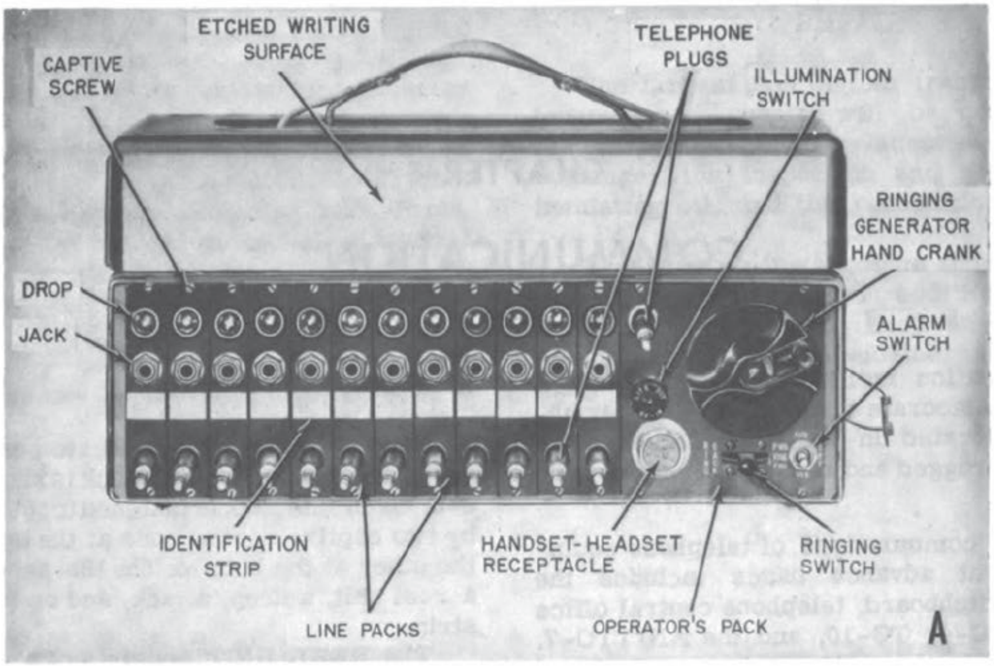
The JACK is used in conjunction with the cord of the operator's pack, or with cords of the line pack, to interconnect line circuits.

The IDENTIFICATION STRIP is a piece of white plastic fastened beneath the line jack. Marks on this strip identify the telephone circuit associated with the line pack.

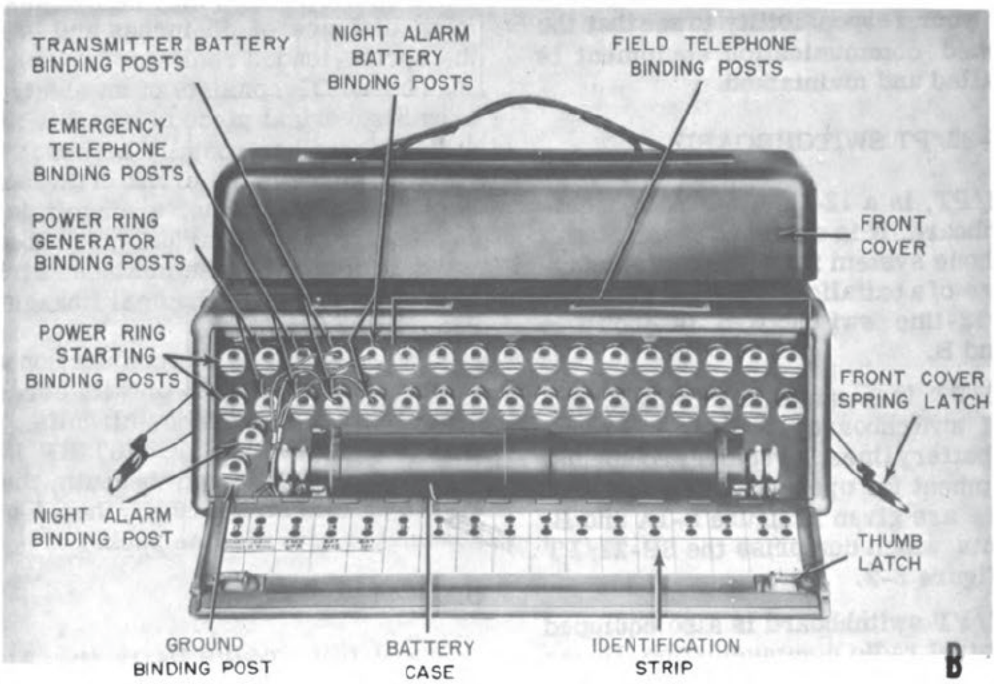
OPERATOR'S PACK

The OPERATOR'S PACK (fig. 8-4) is located on the right of the front panel. The pack consists of a reel unit, ringing equipment, alarm equipment, and a handset-headset receptacle.

The REEL UNIT is identical to that of the line pack. The ringing equipment consists of a hand generator and a control switch. Ringing current



A. Front view



B. Rear view

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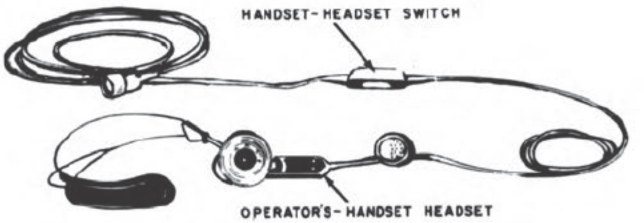
Figure 8-1.—Front and rear view of 12-line switchboard, SB-22/PT.



26.104.3
Figure 8-2.—Manual telephone switchboard SB-22/PT, components.

is generated when the hand crank is rotated. The control switch has two positions: RING BACK and PWR RING FWD. This switch enables the operator to connect ringing current to the calling or to the called telephone.

The ALARM EQUIPMENT provides a more positive signal for the operator than that afforded by the drop mechanism of the line pack. The alarm equipment consists of the signaling buzzer and a lamp. When the switchboard is signaled by an outlying telephone, the drop on the line pack associated with the outlying field telephone falls; this completes a circuit through the alarm lamp or the buzzer depending on the setting of the switch. Either the lamp lights or the buzzer sounds.

The HANDSET-HEADSET receptacle is a polarized, bayonet-locking, 10-conductor receptacle which is used with the plug on the handset-headset cord.

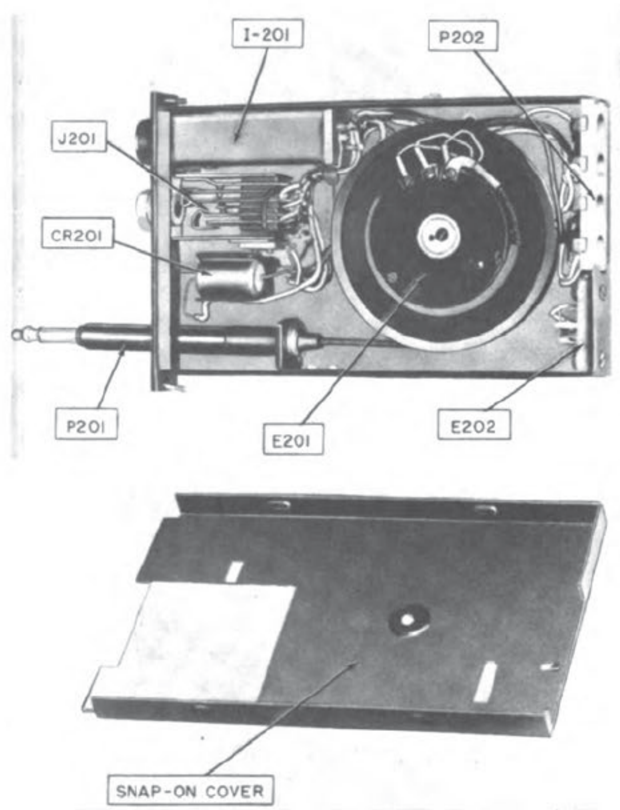
PREINSTALLATION PROCEDURES AND CHECKS

You should inform your crew that the 12-line switchboard may be placed on a surface of the proper height to ensure ease of operation. If a suitable stand is not immediately available, it may be temporarily placed on the ground.

Your crew should be careful not to damage the equipment during uncrating and unpacking. You should have it inspected immediately upon unpacking for possible damage during shipment. The original packing cases and containers should be saved, so they can be used again when the equipment is repacked for storage or shipment.

Before the connections are made, instruct your crew on the proper procedures for testing the line and operator's packs.

After the connections are made and the tests have been completed, talk over the line and note the quality of transmission. If transmission is poor or speech cannot be heard at normal speech level, check the wiring and repeat the tests. If the trouble continues, replace the operator's pack.

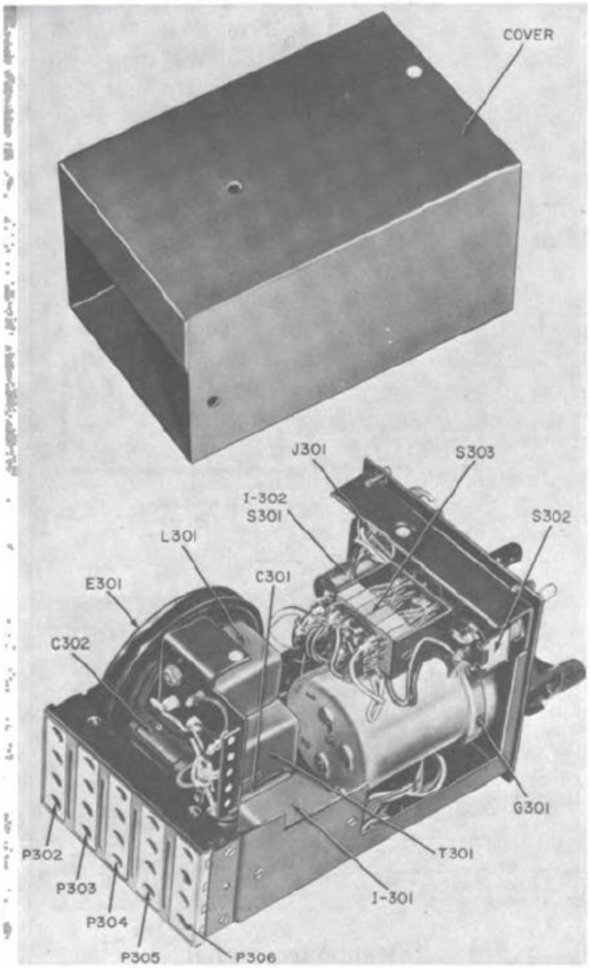


I-201	Switchboard signal
J201	Telephone jack
CR201	Selenium rectifier
P201	Cord assembly
E201	Reel unit
E202	Lightning arrestor
P202	Clip assembly

26.105
Figure 8-3.—Line pack for SB-22/PT switchboard.

INSTALLATION PROCEDURES

The ground connection should be made before connecting the wire lines to the switchboard. Select the lowest, dampest site in the vicinity; clay or loamy soil is best. You should have one of your crew members scoop out a hole 6 inches



P302 P303 P304 P305 P306	Clip assembly
I-301	Night alarm buzzer
T301	Induction coil
G301	Ringing Generator
S302	Night alarm switch
S303	Lever switch (ringing)
J301	Receptacle connector
I-302	Night lamp
S301	Signal lamp switch
C301	Coupling capacitor
L301	Retardation coil
E301	Reel unit
C301	Coupling capacitor

26.106

Figure 8-4.—Operator's pack for SB-22/PT switchboard.

deep and drive a ground rod into the hole until the top of the rod is about 3 inches below the undisturbed ground surface. Have him connect one end of the wire to the ground rod. The earth around the rod should be saturated with water, and the hole filled with earth. Now connect the other end of the wire to the binding post located on the frame behind the rear access door.

To connect the wire lines to the switchboard, a pair of binding posts should be selected and connected to the desired circuit. Be sure to record the circuit identification on the proper identification strip.

When the wire lines are connected, you are ready to install the four dry-cell batteries, which furnish the power. Remove the battery case and insert two BA-30 batteries into the compartment so that the brass contact end of each battery faces outward. Repeat the procedure for the compartment at the other end of the battery case. After completing this operation, replace the case into the spring retaining clips.

STACKING OF TWO SWITCHBOARDS

To serve more than 12 but fewer than 30 lines, stack two 12-line switchboards. Remove the operator's pack from the switchboard and install five line packs in the empty space. This modified switchboard should be placed on top of a normally equipped switchboard. Use two jumpers to connect the two switchboards. One jumper must be connected to the NA binding posts of both switchboards, and the other jumper must be connected to the GND binding posts of both switchboards. Be sure that the jumpers pass through the slot at the side of each switchboard. Only one set of batteries is required to serve both switchboards; the battery case from the one containing the 17 line packs (from which the operator's pack has been removed) should be removed. The field telephones can then be connected as previously described. A maximum of 29 lines can be served with this arrangement.

MAINTENANCE AND REPAIR

See that your crew makes frequent inspections of the equipment to keep it in good working order. Dust, dirt, grease, or moisture should not be allowed on the exterior of the switchboard or the handset-headset. A clean, dry, lint-free cloth or a dry brush should be used for cleaning. The electrical contacts on the frame of the

switchboard should be cleaned with a cloth moistened with dry-cleaning solvent, and should be wiped dry with a clean dry cloth. A burnishing tool should be used to clean the switch contacts.

Rust, fungus, dirt, and moisture tend to accumulate on the binding posts, plugs, and external portions of the line jacks. Have these removed with a dry rag or brush. The battery case and clip contacts should be inspected for corrosion, moisture, fungus, and tightness. All lines should be checked for kinks, strains, moisture, fungus, and loose terminals; also have the insulation checked to see that it is not frayed, cut, or otherwise damaged.

Moving parts of the SB-22/PT do not require lubrication. When necessary, lubricate the spring latches of the front cover, and the thumb latches and hinge of the rear access door.

Failure of the switchboard to operate properly is usually caused by one or more the following:

1. Rundown batteries
2. Defective operator's handset-headset
3. Defective line pack
4. Defective operator's pack

Rundown batteries may be indicated by any of these difficulties:

1. Pull switch is pulled out, but lamp fails to light.
2. Drop of a line pack indicates that a telephone is signaling the switchboard, but the lamp or buzzer of the operator's alarm fails to work.
3. The operator cannot talk to any of the telephone users.

Remove rundown batteries, and replace them in the manner previously described.

A defective handset-headset prevents the operator from talking to any of the telephone users, from receiving calls from any of the outlying phones, or both. Replace defective handset with one that is in working order.

A defective line pack may be indicated by any of the following troubles:

1. The user of a telephone cannot signal the operator because the drop does not function.
2. The drop of a line pack for a particular telephone works, but the operator's alarm fails to function. (If this difficulty occurs with all telephones, the trouble may be rundown batteries or a defective operator's pack.)
3. The operator cannot talk to or receive calls from the user of a telephone.
4. The users of two telephones cannot converse with each other, but the operator can converse with each user separately.

The line pack is a self-contained, plug-in unit. It may be removed by loosening the two captive screws from the front panel, inserting the plug into the jack, and pulling on the plug until the line pack is free from the front panel. The replacement should then be reinserted into the empty space. After the captive screws are tightened, the new line pack is ready for operation.

A defective operator's pack may be indicated by any of the following difficulties:

1. Lamp fails to light when a pull switch is pulled out (also may be caused by burned-out lamp or rundown batteries).
2. The operator's alarm fails to work when the drop of a line pack indicates that a telephone is signaling the switchboard (may also be caused by rundown batteries).
3. The operator cannot ring any field telephone.
4. The operator cannot talk to any telephone users (may also be caused by a defective handset-headset or rundown batteries).
5. The operator cannot receive calls from telephones on the line (may also be caused by a defective handset-headset).
6. The operator cannot ring back.

If at all possible you should always have handy a circuit wiring diagram and exploded views of the various parts of the SB-22/PT switchboard in order to make emergency repairs if spare parts are not available.

TELEPHONE CENTRAL OFFICE SET TC-4

The telephone central office set TC-4 is a transportable switching central consisting of a main distribution frame, telephone switchboard, and accessories. It is designed for use at division or other headquarters which require a switchboard with 40 line circuits (switchboard BD-96). The telephone central office set TC-4 and its components are shown in figure 8-5.

SWITCHBOARD BD-96

Switchboard BD-96 is a complete, transportable, single position, manually operated telephone switchboard. Trunk circuits are provided which may be used for connection to common battery lines of either manual or automatic central offices. Drop signals are provided for the lines and trunks and are associated with each cord for recall signals. A compartment is provided in the rear of the switchboard for

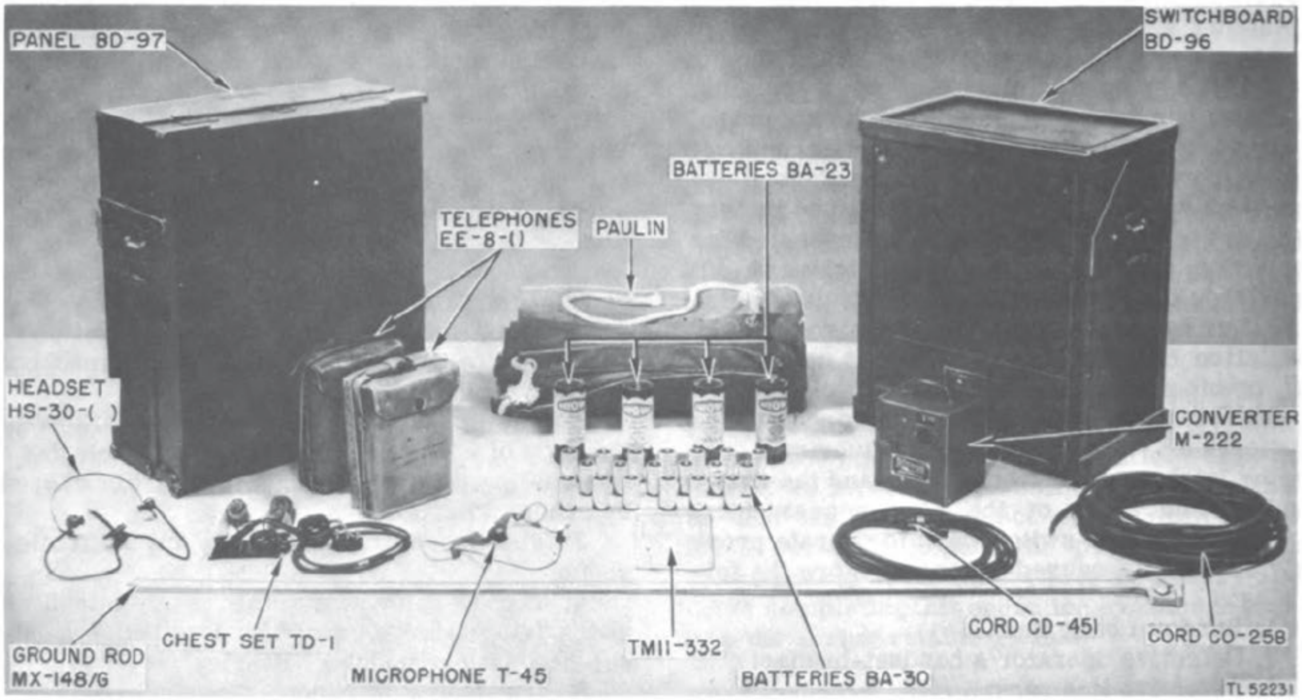


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Figure 8-5.—Components of telephone central office set TC-4.

connection of batteries to supply current for talking and for the night-alarm buzzer. The top of the switchboard contains terminal facilities for ringing current, grouping, a second operator, and external battery.

Switchboard BD-96 contains the following circuits:

1. First operator's telephone circuit and grouping key
12 Cord circuits
1 Ringing circuit
40 Line circuits, magneto
4 Trunk circuits, common battery, manual or dial
1. 1 Dial-cord circuit
1 Conference circuit
1 Night-alarm circuit
1 Second operator's telephone circuit

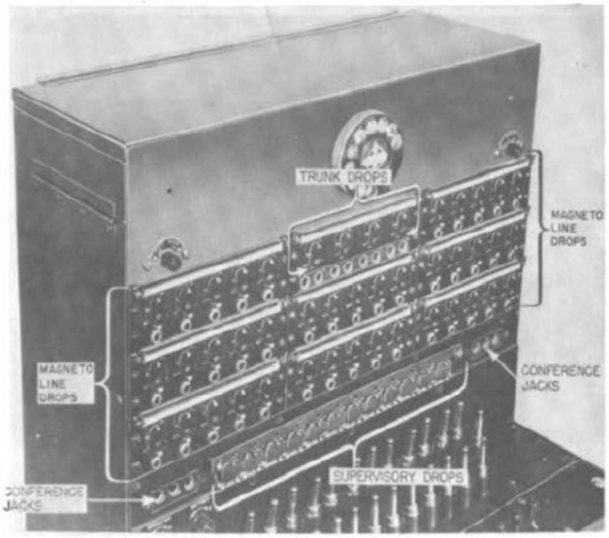
Line Jacks and Drops

Forty magneto line drops and four dial and manual common battery trunk drops with associated jacks are located on the face of the switchboard (fig. 8-6). The magneto line drops are self-restoring; the trunk drops must be manually restored. The drops provided for the four trunk circuits are numbered 35 through 38 and are located in the center of the top row of drops. Each trunk drop has a double jack which provides for dialing.

Binding Post Panel

The line jacks are wired to a binding post panel in the top of the switchboard which provides for connections with spade-terminal strips through rubber-jacketed cable to panel BD-97. The binding post panel contains 90 binding posts in three parallel rows of 30 binding posts per row.

Other accessories on the switchboard BD-96 are the 12 SUPERVISORY DROPS located on the bottom row of the switchboard face (fig. 8-6). These drops are manually restored. There are also 3 CONFERENCE JACKS located to the left and 3 to the right of the supervisory drops. The conference jacks are interconnected so that a six-party conference circuit may be set up on the switchboard. And finally, there are the CORDS and TALK-RING KEYS. The 12 calling cords, 12 answering cords, 1 dial cord, and 12 talk-ring keys are located on the keyshelf of the switchboard. (See fig. 8-7.) Adjacent keys, cords, and supervisory drops are connected internally.



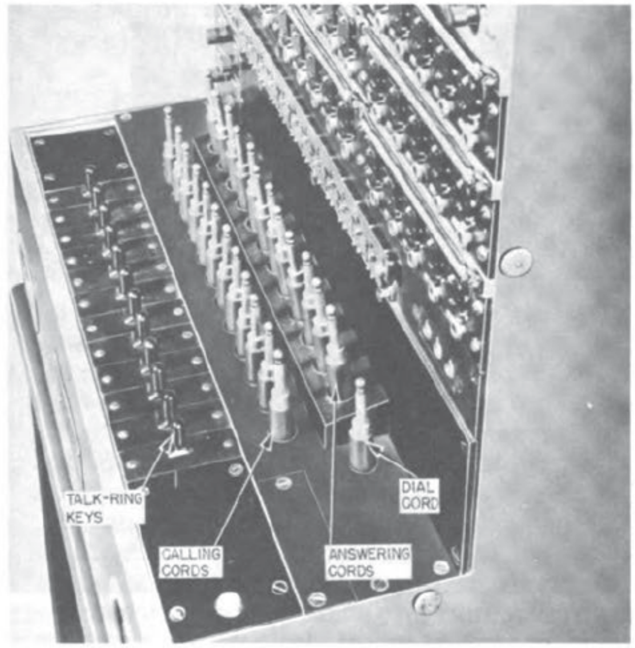
26.108
Figure 8-6.—Switchboard BD-96, front view.

PANEL BD-97

Panel BD-97 is the main distributing frame unit for use with switchboard BD-96. Arrangement of the apparatus is shown in figure 8-8. An opening with a sliding cover is provided for incoming line wires in each side of the panel. An opening with a sliding cover is also provided in the bottom of the upper cabinet for the cables to the switchboard when the cabinet door is closed. Eight repeating coils, four on each side, are mounted on the protectors.

Cables

The cabling between the panel and the switchboard consists of three rubber-jacketed cables each containing 15 pairs of braid-covered latex insulated, No. 22 AWG (American wire gage) stranded conductors. The cables, exclusive of the cable connectors, are 21 feet in length. The cable is connected at the panel directly to the fuses. At the switchboard end the cables are terminated in cable connectors which consist of strips of insulating material between which is mounted a row of 30 spade terminals. These terminals are mounted to allow some movement so that they will be self-aligning when connections are made to the binding posts on the switchboard terminal panel. The cable conductors are soldered to these spade terminals. The soldered connections are enclosed in a copper-alloy protecting cover.



26.109
Figure 8-7.—Switchboard BD-96, keyshelf equipment.

Fuses and Protector Blocks

Two vertical rows of 22 pairs of 1-ampere fuses and protector blocks (unit dischargers) are mounted in the panel. Two terminal strips, each with 44 binding posts, are mounted to each side of the panel for connecting the incoming line wires. These terminals are permanently wired to the line side of the fuses and protector blocks.

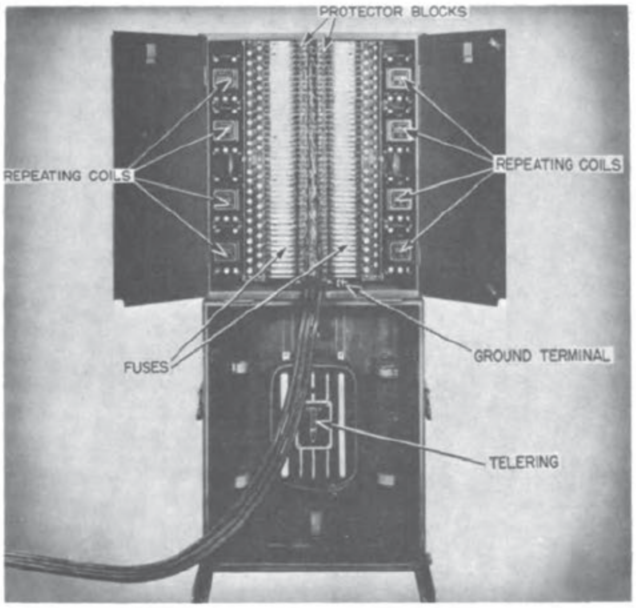
Telering

The telering is mounted in the lower cabinet of panel BD-97 and is used as a source of ringing power when 110-volt, 60-cycle a-c power is available.

INSTALLATION OF TELEPHONE SET TC-4

The equipment is partially weatherproofed and the tarpaulin which is provided can be used as a fly or tent, making it possible for the equipment to function outdoors in almost any kind of weather.

Before the TC-4 telephone set is installed, you should decide upon the general layout in view of the local conditions. Select the driest location available and one that is suitable for



26.110
Figure 8-8.—Panel BD-97 setup, front view.

a good GROUND connection. In selecting the site you should consider the operator. Make sure that the location is as far from extreme noise as practicable so the operator will not be disturbed. Another consideration should be the lighting arrangement. Arrange the equipment so that a subdued light will shine on the operator's work rather than in the operator's eyes.

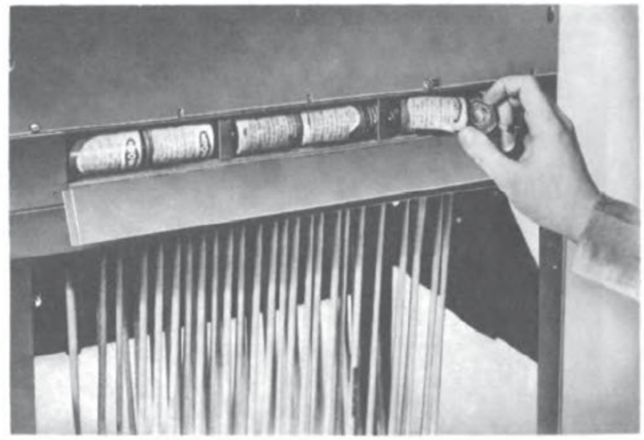
It is not necessary to set up the panel next to the switchboard. In fact, for inside installations, the panel may be placed in another room. The maximum distance between panel and switchboard is limited to approximately 20 feet by the length of the connecting cables. Always place the panel far enough from the switchboard to allow free movement about the panel.

In setting up the switchboard BD-96, make sure that the base is level; then install six batteries BA-30 in the compartment in the lower back of the switchboard as illustrated in figure 8-9.

After the switchboard is set up, make a thorough inspection for damaged or loose parts.

Setting Up Panel BD-97

Installation of the panel BD-97 requires that it be set up with the hinged edge up and within cabling distance of the switchboard.



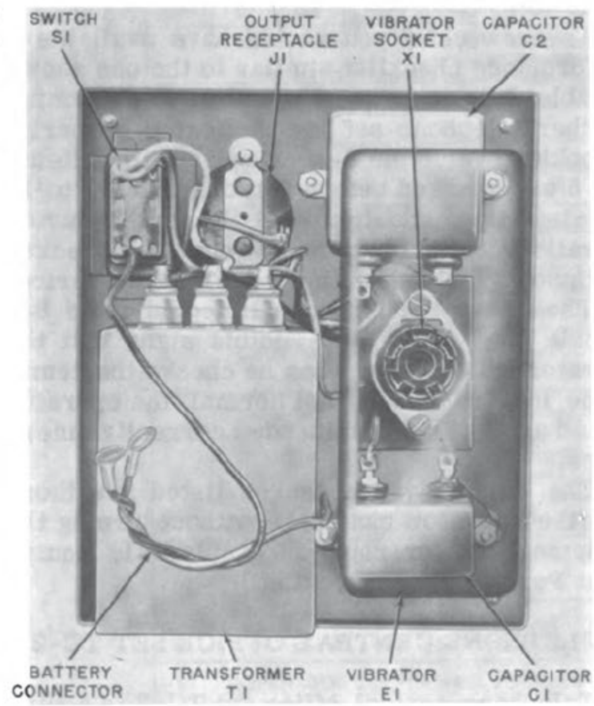
26.111
Figure 8-9.—Installation of batteries in rear compartment of switchboard.

Locate a good ground source, such as a water pipe or other buried metallic object of good conductivity having a large area of earth contact. If this is not available drive a ground rod deeply into moist earth. Use light strokes to prevent whipping of the rod from destroying the earth contact. Tamp the soil firmly down around the rod. If additional conductivity is required a second ground rod of the same type may be driven at least 10 feet away from the first rod and the two connected in parallel. Moistening the surrounding ground with salt water will improve ground conductivity.

Converter

Converter M-222A is designed to supply emergency power ringing current for telephone switchboards such as those for BD-91 and BD-96, when power from a 110-volt, 60-cycle source is not available or when the standard 110-volt power ringing equipment fails in service. Converter M-222A is a standard component of telephone central office sets TC-4 and TC-12. Figure 8-10 shows converter M-222A.

The converter M-222A is housed in a rectangular steel box with two removable sides, which permits easy access to all circuit components by merely unscrewing four captive screws and removing the right cover. Two spring clips are mounted on the inside of the left cover to hold batteries in place.



26.112
Figure 8-10.—Converter M-222A, right cover removed.

Installation of Batteries

Two batteries BA-23, (1 1/2) volt-dry cell) are required for operation of converter M-222A.

In installing the batteries be sure that the two batteries are connected in series using the battery connector. The green wire which is grounded to the case of the converter to the vacant positive terminal of the two batteries, and the red wire is connected to the vacant negative terminal. Be sure that the batteries are placed in the battery compartment with the terminals facing the fiber insulator.

Connection of Converter

To connect the converter for use, plug the power ringing cord from the switchboard into the output receptacle. On converter M-222, the receptacle is located on the front of the converter. On the M-222A, the receptacle is located on the right cover. After the connection is made throw the switch to the ON position to start the converter.

CAUTION: When the converter is not in use, always throw the switch to the OFF position to prevent batteries from being discharged.

PREVENTIVE MAINTENANCE

Although the converter has a small number of component parts, routine preventive maintenance is required for various reasons. For example, ruts encountered on dirt roads during cross-country travel filters into the equipment no matter how much care is taken to prevent it. Rapid changes in weather, (such as heavy rain followed by sunshine and high temperatures), excessive dampness, snow, and ice tend to cause corrosion of exposed surfaces and parts. Without frequent inspections and the necessary tightening and cleaning operations, equipment becomes undependable and may break down when it is most needed.

Inspection is the most important operation in the preventive maintenance program. A careless observer will overlook the evidences of minor trouble. Although these defects may not interfere with the performance of the equipment, valuable time and effort can be saved if they are corrected before they lead to major breakdowns. Make every effort to have your crew become thoroughly familiar with the indications of normal functioning so that they will readily recognize the signs of a defective set. Have them check for the following conditions:

1. Overheating, as indicated by discoloration, blistering, or bulging of the parts or surface of the container; leakage of insulating compounds; oxidation of metal contact surfaces.

2. Placement, by observing that all leads and cabling are in their proper positions.

3. Cleanliness, by carefully examining all recesses in the unit for accumulation of dust, excessive moisture, and so on, especially between connecting terminals. Parts, connections, and joints should be free of dust, corrosion, and other foreign matter. In tropical and high-humidity locations, look for fungus growth and mildew.

4. Tightness, by testing any connection or mounting which appears to be loose.

CAUTION: Do not tighten screws, bolts, and nuts carelessly. Fittings tightened beyond the pressure for which they are designed will be damaged or broken. Whenever a loose connection is tightened, moistureproof and fungiproof it again by applying varnish with a small brush.

CONNECTING TC-4 COMPONENTS

All connections between components of telephone central office set TC-4 are shown in the cording diagram in figure 8-11 and are connected as follows: (Not necessarily in this order.)

1. Connect all three panel cables to top compartment of the switchboard. Match the numbers marked on the cable terminals with the numbers marked at each end of the terminal strips in the top of switchboard BD-96. Tighten all screws with the proper size screwdriver.

2. Connect the ground terminal in panel BD-97 to the ground rod.

3. Connect the incoming lines to the binding posts in the upper cabinet of panel BD-97. Arrange the lines neatly and out of the way to minimize trouble and facilitate troubleshooting. All connections should be made firm and the loose ends of wires trimmed in order to eliminate the possibility of short circuits.

4. Plug the cord of the telering into a convenient 110-volt, 60-cycle outlet. (If none is available use the converter M-222 or M-222A mentioned earlier.) Extend ringing current to switchboard BD-96 by means of cord CD-451.

5. After all other connections have been made, connect headset HS-30 and the necessary chest set.

PERFORMANCE CHECKLIST

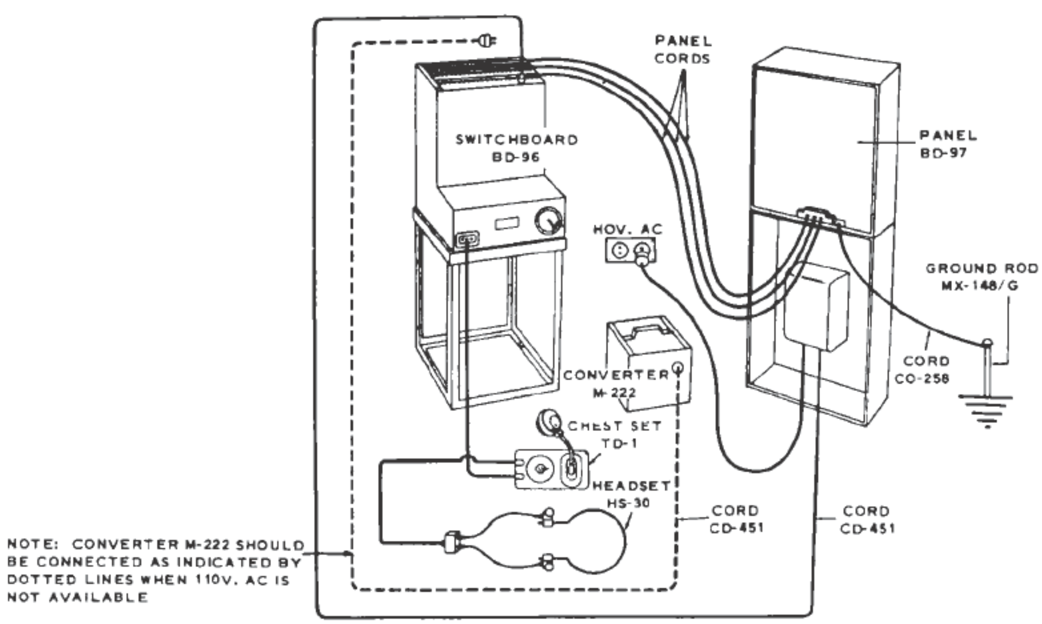
As crew chief you should have available a performance checklist similar to the one shown in table 8-1, to help the operator to determine whether telephone set is functioning properly. In looking over table 8-1 you will note that items 1 to 6 are checked before starting, items 7 to 13 when starting, and items 14 through 16 during operation. Items 14 through 16 should be checked continuously during the normal operating period.

The normal indications listed in table 8-1 include the visible and audible signs that the operator will receive when he checks the items. If the indications are not normal, the operator should apply the recommended corrective measures.

The corrective measures listed are those that the operator can make without turning the equipment in for repairs. (Table 8-1: Equipment Performance Checklist.)

TELEPHONE CENTRAL OFFICE SET TC-2

Telephone central office set TC-2 is equipped with a 57-line switchboard. This switchboard consists of 20 magneto (local-battery) lines and 37 common-battery lines. A switchboard of this type is designed for a base where the majority of telepones are in a centrally located area, but



26.113

Figure 8-11.—Telephone central office set TC-4, cording diagram.

	Item No.	Item	Action or Condition	Normal Indications	Corrective Measures
PREPARATORY	1	Panel cables	Connected to three rows of binding posts in top of switchboard BD-96.		
	2	Panel binding posts	Incoming lines connected.		
	3	Ground Rod MX-148/G	Installed and connected to ground terminal of panel BD-97.		
	4	Batteries BA-30	Six batteries installed in rear of switchboard BD-96.		
	5	Telering	Connected to a-c outlet, if available. Also connected to switchboard BD-96.		
	6	Converter M-222	Connected to switchboard BD-96 if 110-volt, 60-cycle, a-c power is not available.		
	7	Chest Set	Plug into switchboard BD-96.		
START	8	NIGHT ALARM key	Move to ON position for audible signal.		
			Move to OFF position when audible signal is not desired.		
	9	GROUPING key	Move to OFF position for single switchboard operation.		
			Move to ON position if two switchboards are grouped together.		
	10	OPERATOR 1-2 key	Move to 1 position for single switchboard operator.		
			Move to 2 position for two switchboard operators.		
	11	RINGING HAND-KEY key	Move to HAND for hand generator ringing		
			Move to KEY for power ringing.		
	12	BATTERY 1-2 key	Move to 1 position for operation on first set of transmitter batteries.		
			Move to 2 position for operation on second (spare) set of transmitter batteries installed in rear compartment of switchboard.		
	13	EXT. BAT. key	Move to OFF position for normal operation.		
			Move to ON position if external battery is connected to binding posts in top of switchboard.		
EQUIPMENT PERFORMANCE	14	Magneto line and night-alarm circuits	Distant station rings into switchboard.	Drop shutter falls.	
			NIGHT ALARM key in ON position.	Buzzer operates.	Check batteries.
			Insert answering plug into line jack.	Shutter is restored to normal position.	
	15	Cord and first operator's telephone circuit	Operate TALK-RING key to TALK.	Conversation is possible between operator and distant station.	Check batteries.
	16	Ringing and supervisory circuits.	Insert calling cord into desired line jack and operate TALK-RING key to RING. (RINGING key in KEY position.) If using hand generator (RINGING key in HAND position), crank the hand generator.	Bell of called station rings and station answers.	Check ringing source and connections from power ringing equipment.
			Distant station rings back.	Supervisory drop falls.	

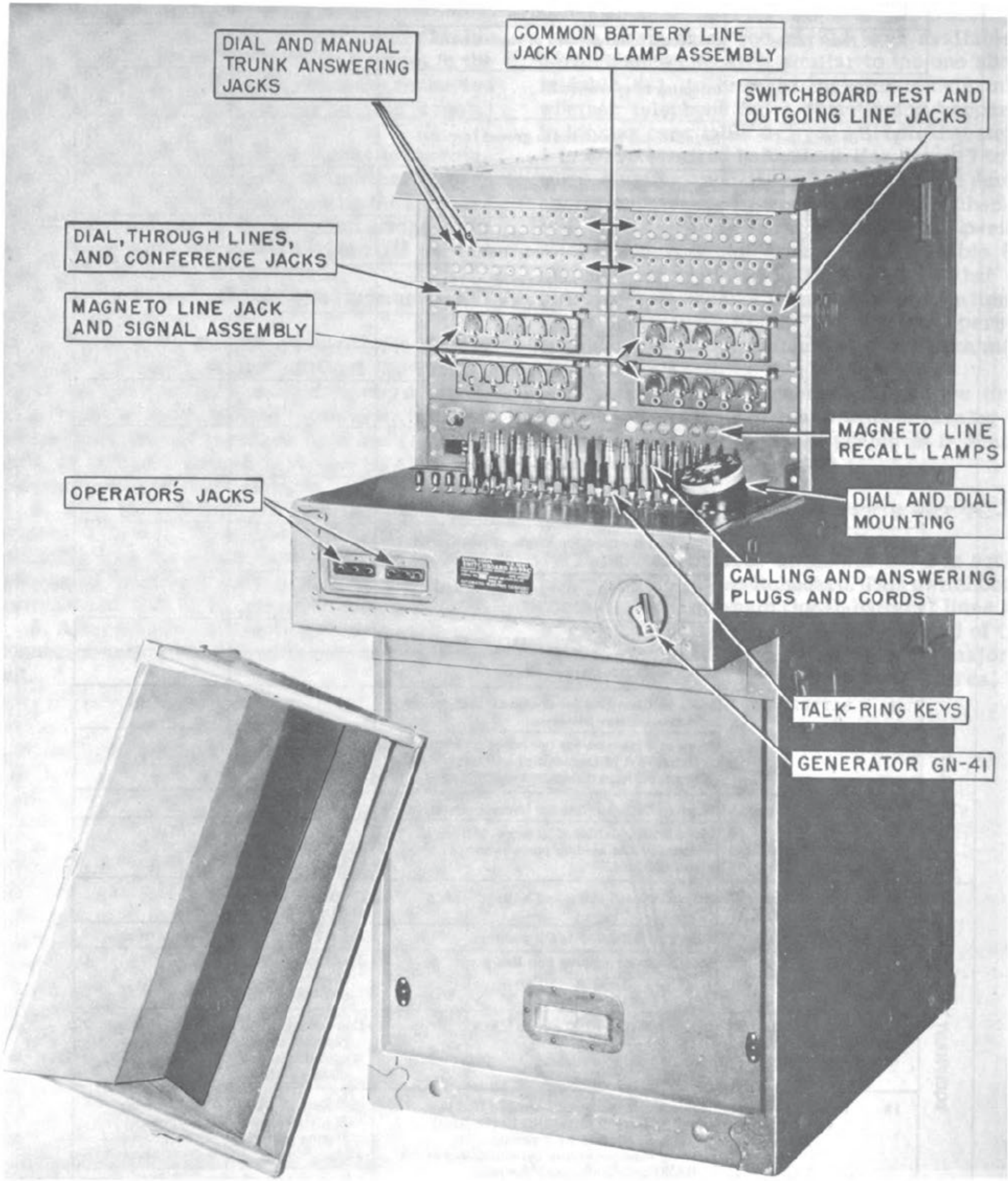


Figure 8-12.—Switchboard, BD-89C. 26.114

where a few telephones are located in outlying activities. Telephones located a considerable distance from the exchange require local-battery operation.

The complete switching system consists of the 57-line switchboard, a main distributing frame (MDF), a power panel, a rectifier, a power unit, and necessary accessories.

The switchboard is the Army Signal Corps-type BD-89. It is a portable, single-position, two-panel, manually operated type. In addition to the 57 telephone lines, it contains three trunklines which may be connected to other switchboards. One trunk circuit provides for two-way service between the switchboard and a dial central office. A dial cord circuit is provided for dialing on the trunk circuit. Lamp signals are provided for the common battery lines and the cord circuits.

Drop signals are provided for the magneto lines, with magneto recall lamps associated with each cord circuit. The line jacks are wired to a terminal strip at the rear of the switchboard which provides for connections with spade terminal strips through rubber-jacketed cables to the main distribution frame. Terminal facilities are provided for making connections to the storage battery supply (24 volts DC), ringing current supply, and grouping key circuit. One model of the BD-89 switchboard is shown in figure 8-12.

MAIN DISTRIBUTING FRAME

The main distributing frame serves to terminate the outside lines and to connect them to the proper line jacks on the switchboard. Cabinet BE-79 (fig. 8-13A&B) is the MDF used with the BD-89 switchboard. The MDF is equipped with protector blocks and heat coils which are connected to terminal strips. Binding posts are provided for the incoming lines and for cross-connecting, so that all such connections can be made without soldering. There are twelve repeating coils mounted on the line side of the MDF to permit cross-connection and cabling.

The line side of the cabinet contains two vertical strips of protectors, each strip consisting of 40 pairs of protector blocks and heat coils. The heat coils guard against the cumulative effects of small currents that might produce excessive heat when they flow for considerable periods of time. A terminal panel equipped with 80 binding posts for connecting the incoming lines is mounted on the line side of the protectors. The central office side of the protectors is permanently wired to terminal panel equipped with 80 binding posts from which the lines may be cross-connected to the switchboard cable connector binding post terminals or repeat coils.

The switchboard side has three cable connectors. Each connector consists of a strip of insulating material equipped with a row of 50 binding post terminals (25 pairs) to which the switchboard cable conductors are soldered. The cables, exclusive of cable connectors, are 21 feet long. Each cable connector at the switchboard end of the cable is made up of two strips of insulating material between which is mounted a row of 50 spade terminals, so mounted that some movement is allowed.

The 12 coils on the coil rack are mounted directly below the protectors in two horizontal rows of six coils per row. Each coil is mounted separately to simplify removal if replacement is required.

OTHER AUXILIARY EQUIPMENT

Other auxiliary equipment necessary to operate the switchboard includes a power service panel, power unit, junction box, accessories (headset, chestset, ground rods, and cords) rectifier, storage batteries, and a power distribution or control panel. The latter serves both to control the rate of charge of storage batteries and to provide ringing current to the switchboard.

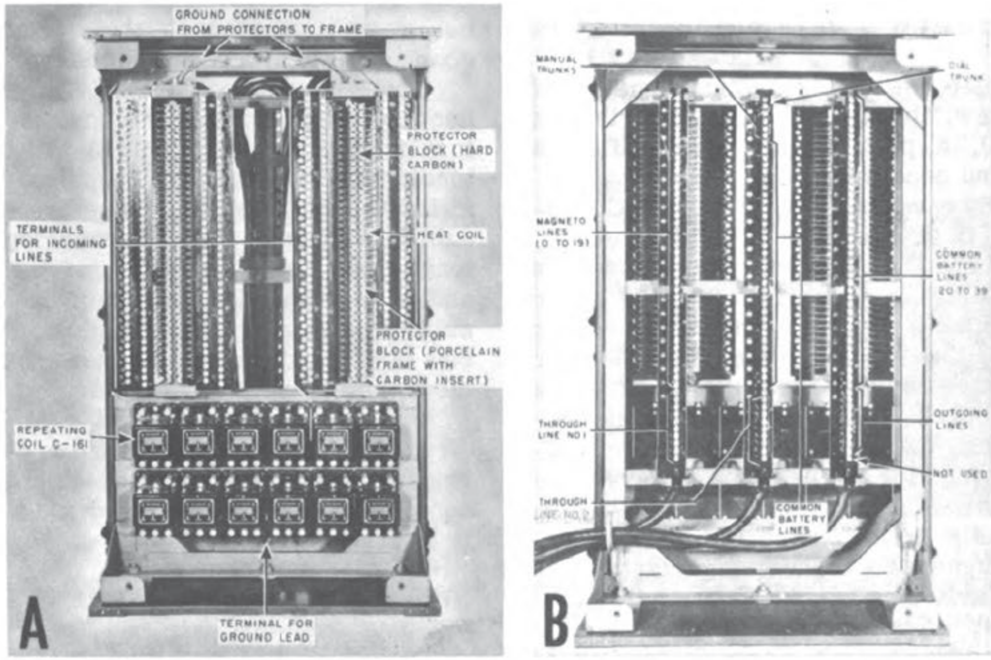
The power service panel (fig. 8-14) is designated cabinet BE-75. In figure 8-14, it is mounted on a rack, along with a rectifier and filter reactance. Cabinet BE-75 contains two sockets and two outlets for the connections of the rectifier and the other power cords. Three circuit breakers control the current to the sockets.

The power unit will most likely be a gasoline driven a-c generating set designed to generate 120-volt, single-phase, 60-cycle current. The power unit is used only if another source of power is not readily available.

The junction box (JB-19) provides a means of bringing in 24 volts direct current, 20-cycle, a-c ringing power, to the switchboard. It may also be used to extend a power to a second switchboard and to group the current between the two switchboards.

The headset and chestset make up the operator's telephone set. The ground rod is used to provide the connection to ground required for protection of the switchboard equipment.

The rectifier serves to convert alternating current into direct current which is necessary



26.115

Figure 8-13.—Cabinet BE-79, main distributing frame. a. Line side. b. Switchboard side.

to operate the switchboard. Storage batteries serve as an emergency source of power. The rectifier will most likely be of the selenium-disk type (RA-91), but the vacuum-tube type is also used (RA-36).

The panel which controls the rate of charge of the storage batteries is designated panel BD-98 (fig. 8-15). The power distribution panel also contains two interrupters which are used to supply ringing current to the switchboard. Interruptor PE-250 supplies the current when a-c power is available, and interrupter PE-248 provides ringing current when only battery power is available.

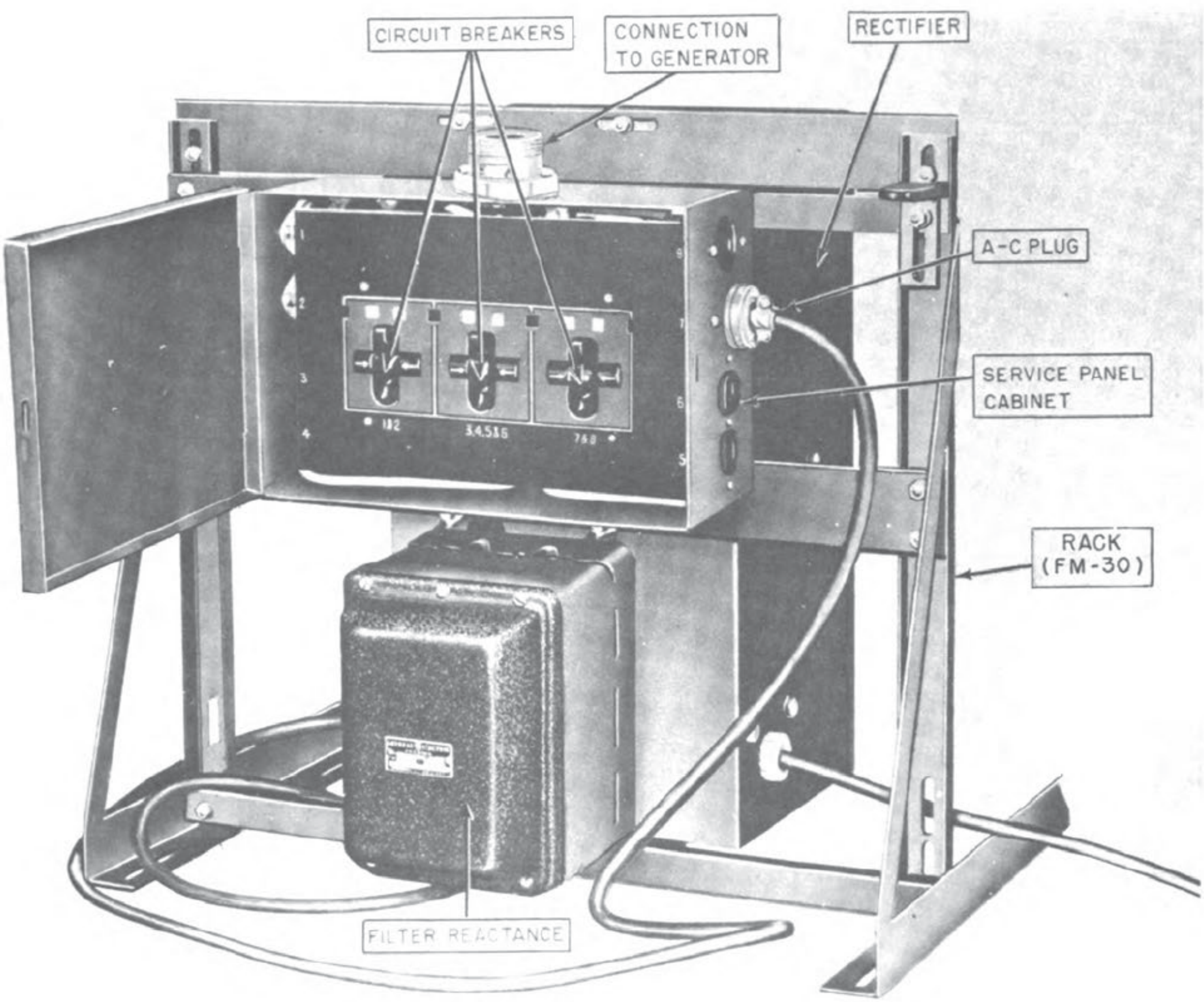
INSTALLATION

One of the problems of installing a telephone central office set is to determine the most satisfactory location. It should be centrally located so the length of the telephone lines can be kept to a minimum. The main distribution frame should be located near an outside wall to facilitate bringing the telephone lines into the building for termination. The switchboard should be placed where it will give the operator maximum signal visibility. It should usually be located with the face at right angles to the window to prevent direct light from hitting the eyes of the operator. A space of at least 30 inches must be provided between the back of the switchboard and any wall or obstruction; this permits easy access to the rear for maintenance and repair. A clearance of at least 2 feet should be maintained at a side of the switchboard that is adjacent to an area that is to be used as a passageway. A minimum of 40 inches should be allowed between the keyshelf and the nearest wall or obstruction; about 6 feet is considered ideal. The batteries must be located as far from the switchboard as possible, due to explosive and corrosive fumes given off by the batteries. Place the batteries near a window for ventilation.

After the switchboard is placed in the desired location, see that proper installation procedures are followed. First, remove the two covers and remove the silica gel from the cabinet. Disconnect the switchboard end of cord CD-298 from the cabinet.

Set the two storage batteries on rack FM-31 and place the rack within cable distance of control panel BD-98. Place the power unit within cable distance of panel BD-98, and have the components properly connected.

If possible, the ground source should be a water pipe or similar buried metallic object of



26.116

Figure 8-14.—Cabinet BE-75, front view.

good conductivity, having a large area of earth contact. If such a ground source is not available, drive three ground rods deeply into moist earth at least 10 feet apart. Use the procedure for grounding as mentioned in setting up the BD-97 earlier.

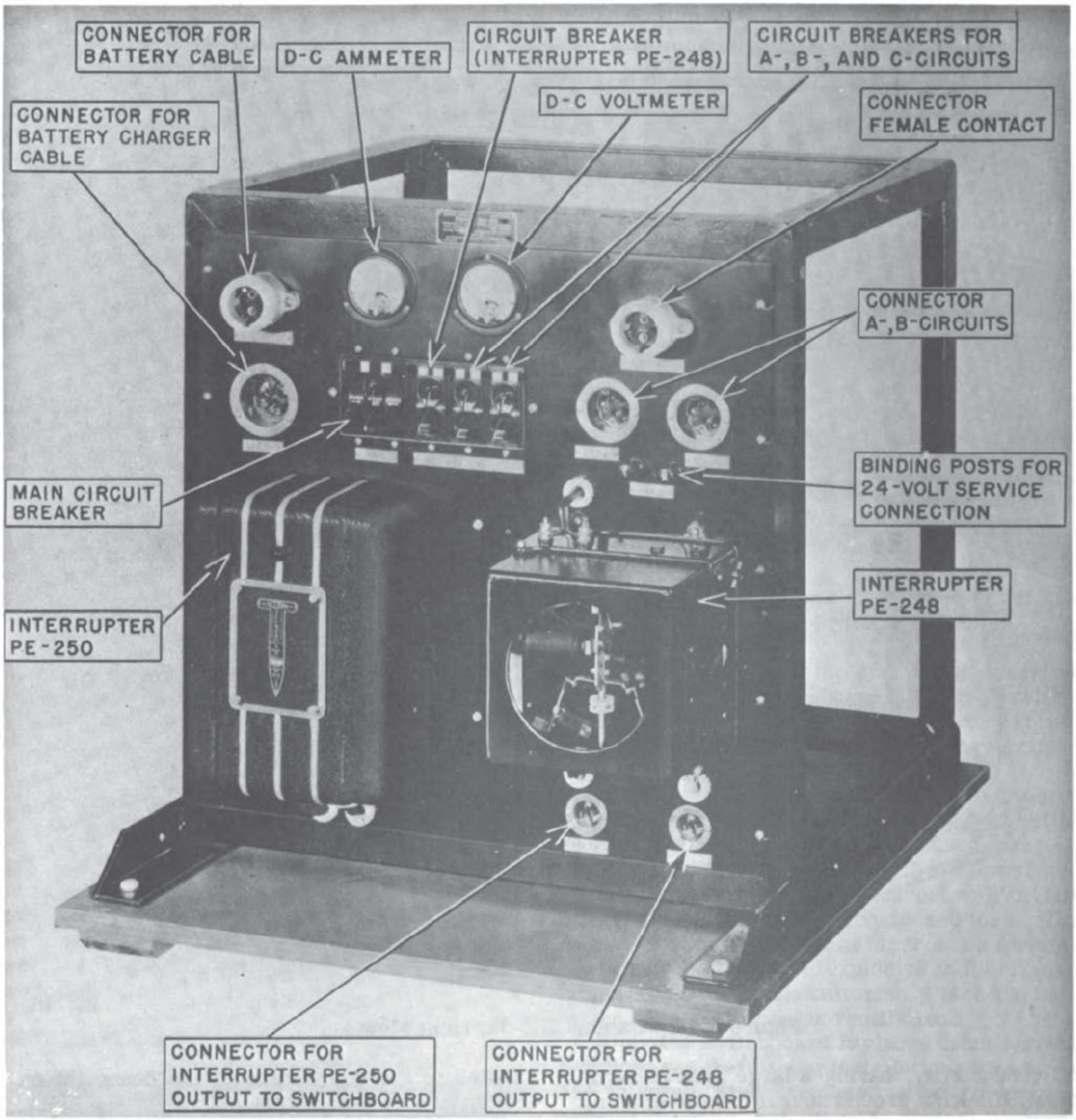
MAKING THE CONNECTIONS

The connections between components of the set are shown in figure 8-16. If 110-volt, 60-cycle, a-c power is available, connect cord CD-393 to the source and to the connector on the top panel of cabinet BE-75.

Be sure that the junction box JB-19 is properly mounted in the switchboard and fasten the switchboard spade terminal cable connector to the junction box.

PREVENTIVE MAINTENANCE

A preventive maintenance program may be divided into four basic operations: (1) inspecting, (2) tightening, (3) cleaning, and (4) adjusting.

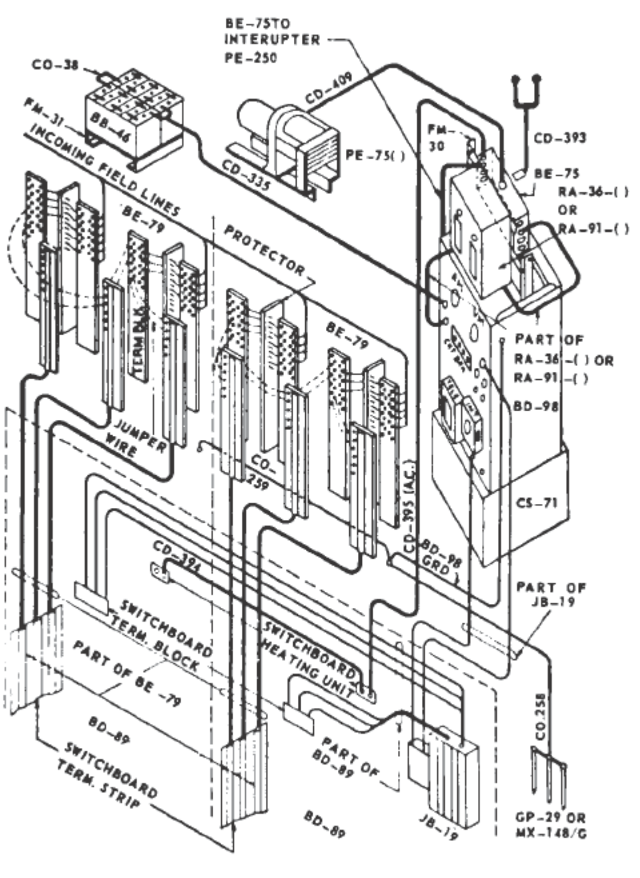


26.117

Figure 8-15.—Panel BD-98, front view.

Inspection is the most important of these operations. Minor defects, which do not interfere with the performance of equipment, but which may lead to a major breakdown, can usually be located during a careful inspection. During inspection your crew should check for the following conditions:

1. Evidence of overheating as indicated by discoloration, blistering, or bulging of the parts



26.118
Figure 8-16.—Telephone central office set TC-2, cording diagram.

or surface of the container; leakage of insulation compounds; or oxidation of metal contact surfaces.

2. Placement, by observing that all leads and cable are in their original positions.

3. Cleanliness, by examining all recesses in the units for accumulation of dust. Parts, connections, and joints should be free of dust, corrosion, and other foreign matter. In tropical and high humidity locations, look for fungus growth and mildew.

4. Tightness, by testing any connections or mountings that appear to be loose.

Daily Inspection

Assign someone to make a daily inspection of the switchboard exterior, night alarm bell, headset, chestset, exterior of MDF, storage batteries, and control panel BD-98 in accordance with the following checklist:

1. Wipe off any dirt or dust with a soft, dry cloth; never use soap and water.

2. Clean the surface of the switchboard key shelf with a soft bristle brush.

3. Pull the switchboard cords up as far as possible and let them hang down over the key shelf and dust along the cord rail, being careful to prevent foreign objects from getting into the cord sockets.

4. Examine the MDF and check for damaged places, chipped paint, dirt, rust, corrosion, and loose, or missing screws. When tightening the screws, be careful not to force them.

5. Make the same checks on control panel BD-98 as on the MDF; in addition, inspect the cable connections to the panel, and examine interrupter PE-248 and the meters for cracked or broken glass. Remove dirt, dust, and lint from the wiring on the rear of the panel with a soft bristle brush.

6. Inspect the batteries and check the specific gravity and level of the electrolyte in addition to checking for cleanliness and tightness of connections. Remove corrosion from the battery terminals with fine sandpaper or crocus cloth.

The night alarm bell should be inspected whenever a new operator comes on duty. He should test it by operating the NA key to the ON position and allowing one of the drop shutters to fall to the operated position. The night alarm bell will sound if the system is working properly. The exterior of the headset and chestset should be examined for dirt, dust, rust, and corrosion. In addition, the chestset should be checked for chipped paint or fungus growth. In wiping off the chestset be careful to keep dirt or lint from getting through the holes into the face of the transmitter.

Weekly Inspection

Weekly inspections should be performed on the drop shutters, switchboard cords, keys, fuses, protector blocks, heat coils, repeating coils, and ground rods. Examine the drop shutters for bent or damaged latches or bent hinge pins. If necessary, adjust the shutter latches with the long-nose pliers to prevent the shutters from falling to their operating position when the switchboard is jarred. Bend the latch so that the shutter will fall freely when a call is received, but will not drop to the operating position when jarred.

The switchboard cords should be examined for dirt, dust, mildew, and fungus. Check the cord weights and pulleys for smooth operation.

Inspect the keys for tightness of mounting and loose, cracked, or broken handles. In tightening the two screws that hold the keys in place, be certain to use the proper size screwdriver. A screwdriver that is too large damages the screw slots and the bakelite cover. Tighten the key handles with the fingers, being careful not to exert pressure so great as to cause the handle to crack.

Check the fuses for correct capacity and tightness of mounting; tighten mounting screws securely, but be careful not to damage the fuse by using too much force.

Examine the protector blocks for cracked or broken porcelain and carbon blocks, dirt dust, and foreign matter. Replace any blocks that are chipped or broken. Clean the blocks with a soft bristle brush; remove any foreign object which may be lodged between the protector blocks. Use extreme care when brushing or you may dislodge a block, thus causing trouble on an incoming line.

Inspect all heat coils for cleanliness and for chipped or broken shells. Clean with a soft bristle brush. Replace any that are defective.

The repeating coils should be checked for cleanliness and corrosion. Do not remove the metal covers of the coils. Examine the coil mountings for loose, damaged, or missing screws. Clean the coils with a clean, dry cloth.

Inspect the ground rods for rust and corrosion. See that the wing bolt at the terminal connection is tight.

Monthly Inspection

Plugs, relays, capacitors, terminals, binding posts, and cables, should be checked on a monthly inspection. The switchboard plugs should be cleaned with cord plug polish, using a clean dry cloth. All residue from the polish should be removed after cleaning in order to maintain good electrical contact.

The terminals and binding posts on the switchboard and control panel should be inspected for cleanliness and tightness. The incoming line connections should be checked for good electrical contact. Tighten any loose terminals with a proper size screwdriver or wrench. The terminals and binding posts should be cleaned with a soft bristle brush.

The connecting cables should be examined for worn or damaged insulation. The fittings on the ends of the cables should be checked for tightness and good electrical connection. The connections on the cables should be tightened as required.

TROUBLESHOOTING AND REPAIRS

When trouble in a telephone system arises, the first step in effecting repair is to assign appropriate members of your crew to determine the probable cause of the trouble. Schematic diagrams are useful in localizing the fault to a particular component. Ensure that a complete visual inspection of the wiring and connections to the associated equipment is made. If no wires or connections are broken, the trouble must be located by having continuity, voltage, and resistance measurements checked. The circuit can be followed by using a systematic process of elimination. With this method the fault can normally be located within a short time. The individual working on the circuit should start at a point where the analysis has shown the circuit to be good and proceed step by step, eliminating parts of the circuit, until the fault is located.

If visual inspection fails to reveal the source of trouble, electrical testing equipment should be used. The schematic and wiring diagrams must be carefully studied, and tests made until the trouble is located.

The use of a troubleshooting chart will simplify fault location. Charts are designed for locating troubles in various models of switchboards and equipment. Various troubles are listed, together with the probable location and the recommended correction. By using these charts, troubles can frequently be isolated to one part of the equipment, thus saving time-consuming checks on trouble-free components.

Many repairs can be effected by simply replacing a fuse, lamp, cord plug, strap, or similar item. Other repairs require nothing more than cleaning a contact, cord plug, or grouping key. Adjusting a screw, a spring, or line drop will often make equipment operable.

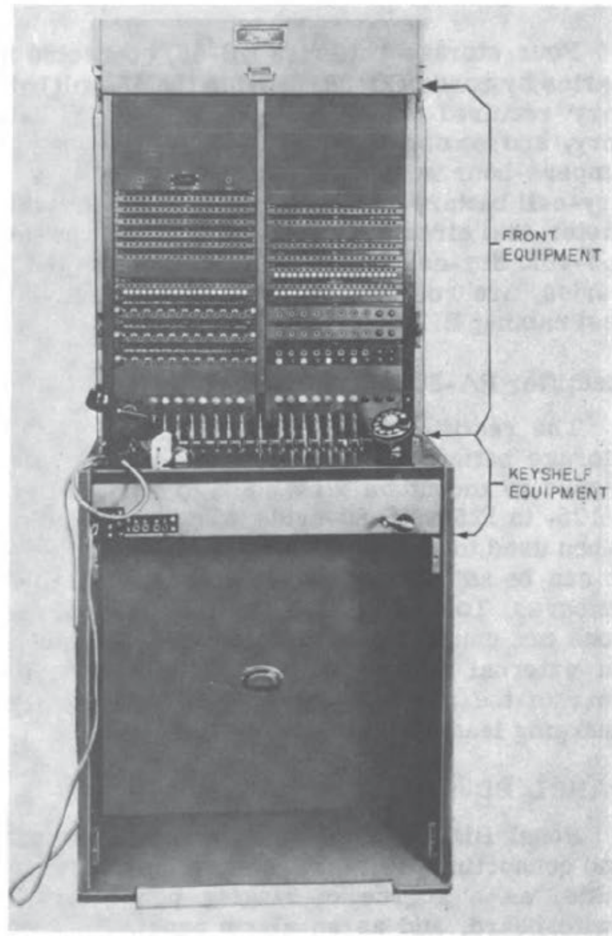
Some repairs, of course, are rather complex, as for example repairs to switchboard cords and repairs to combined jacks and signals. Space does not permit a discussion of all such repairs. The Army Technical Manual, TM11-340, which describes the TC-2 telephone set, contains a complete discussion on all phases of maintenance and repair for the switchboard and associated parts.

TELEPHONE CENTRAL OFFICE SET TC-10

Telephone SET TC-10 is a complete transportable telephone central office for use at any advance base requiring a telephone switchboard of the capacity of 1 to 6 switchboards BD-110. The number of switchboards to be used in an installation is determined by the number of lines to be served and by the expected maximum calling rate. For each switchboard BD-110 used, a maximum of 60 common-battery lines, 30 local-battery (magneto) lines, and 4 two-way trunks may be connected, and a maximum of 15 conversations can be handled at one time. The magneto line circuits can be used for magneto lines, toll lines, or interoffice, two-way ring-down trunks. The trunk circuits may be used for trunks to manual or automatic (dial) exchanges. The anticipated normal installation is three switchboards BD-110, and this number will normally be furnished with telephone central office set TC-110.

SWITCHBOARD BD-110

The switchboard BD-110 (fig. 8-17) is a single-position, two-panel, manually operated telephone switchboard. The lower section of the switchboard contains the cords and a rack upon which are mounted the cord circuit relays, operator's telephone circuit apparatus, universal trunk circuit apparatus, and switchboard fuses. The upper section of the switchboard is occupied by the jack and signal equipment, the cabling therefrom, and the terminal panel. The terminal panel is formed by one section which, supported by top bolts, can be swung out for access to the jack and signal equipment and wiring. The terminal panel provides 800 binding posts in 16 vertical rows of 50 binding posts per row. Lamp signals are provided for signaling on magneto lines. Multiple jacks are provided for use when two or more switchboards are used. The answering and multiple jacks are wired to flexible cables which are equipped with spade terminal strips. These strips are arranged for connection to the binding posts on the terminal panel of the same or another switchboard. This arrangement permits making rapid multiple jack connections between switchboards. A smaller spade terminal strip with four flexible cables permits connections to battery, ringing, alarm, and grouping circuits. The cord circuits are fully universal, and can be used to interconnect all lines and trunks.



26.119
Figure 8-17.—Switchboard BD-110, front view

Each switchboard BD-110 contains the following circuits:

1 Operator's telephone circuit
1 Auxiliary operator's telephone circuit
1 Dial-cord circuit
30 Local-battery (magneto) line circuits
60 Common-battery line circuits
4 Universal trunk circuits
15 Cord circuits (fully universal)
1 Power and heating circuit
1 Conference circuit (10 jacks)
1 Grouping key circuit
1 Emergency-ringing circuit
1 Keyshelf and framework ground circuit

POWER EQUIPMENT

Batteries

Four storage batteries BB-46, connected in series by cords CO-38, provide the 48-volt battery required for relay operation, talking battery, and so on. Battery BB-46 is a 12-volt, 75 ampere-hour sealed type battery. One 45-volt dry-cell battery BA-26 is required for the voltmeter test circuit of cabinet BE-72, and twenty 1.5-volt dry-cell batteries BA-23, connected in series, are required to furnish 30 volts for the test cabinet BE-70.

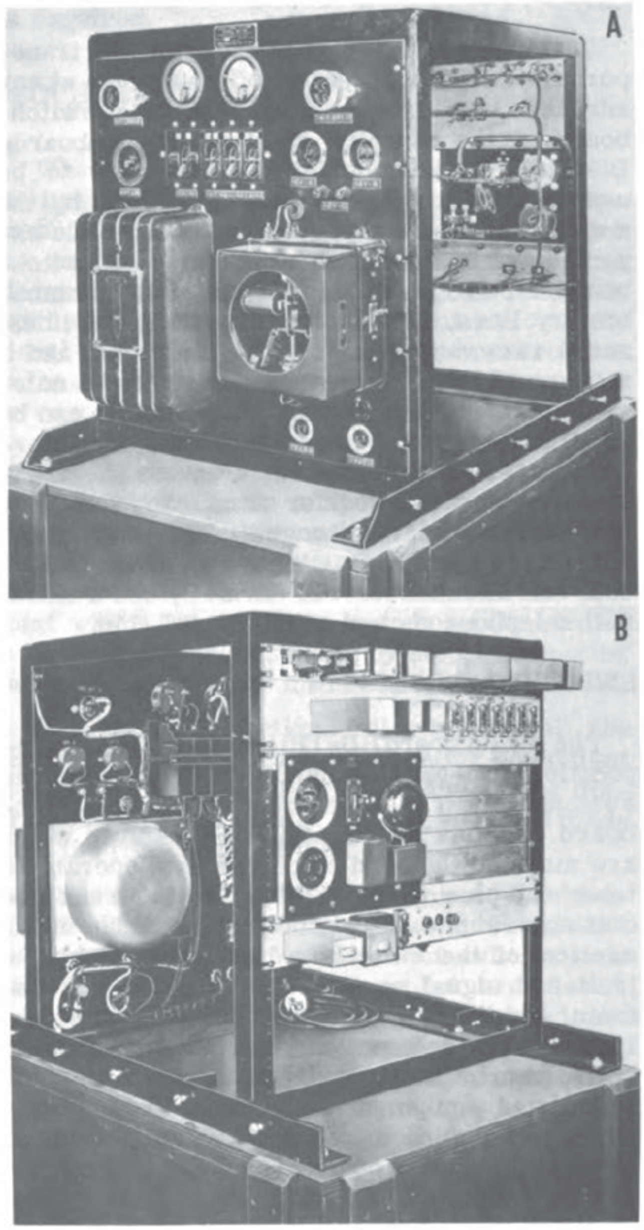
Rectifier RA-36

The rectifier is used to charge the 48-volt storage battery. It is a full-wave rectifier designed to mount on a rack and to operate from a 105- to 125-volt, 60-cycle, a-c power source. When used to charge a 48-volt (24-cell) battery, it can be adjusted to charge at a rate of 2 to 12 amperes. To ensure that the charging current does not cause noise in the telephone circuits, an external filter reactance, mounted on the rear of the rack, is connected in the positive charging lead.

PANEL BD-90

Panel BD-90 (fig. 8-18) serves as a control and connecting point for the 48-volt battery circuits, as a source of ringing power for the switchboard, and as an alarm panel. The front panel is equipped with receptacles and binding posts for connection to the battery and rectifier, and to the switchboard or other equipment requiring 48-volts direct current. Circuit breaker switches on the panel control the power supply to the switchboard or other equipment, and in addition protect these circuits against overload. The lower part of the front panel is equipped with a telering (vibrator-type) power ringer to obtain 90-volt, 20-cycle ringing power from a 110-volt, 60-cycle supply. It is also equipped with a vibrating interrupter which has a ringing transformer to obtain ringing power from the 48-volt storage battery. Equipment is mounted on the rear panel for the following circuits:

1 Contact protection circuit for the ringing interrupter
1 Night alarm circuit (including the battery supply fuses for the line lamps on the switchboard)



26.120
Figure 8-18.—Panel BD-90, A. front view B. rear view.

1 NO-voltage alarm circuit (ringing voltage alarm)
1 Fuse alarm circuit
1 Voltage supply circuit for cabinet BE-72 voltmeter test circuit

POWER SUPPLY

The telephone central office set TC-10 is designed to operate on a commercial source of

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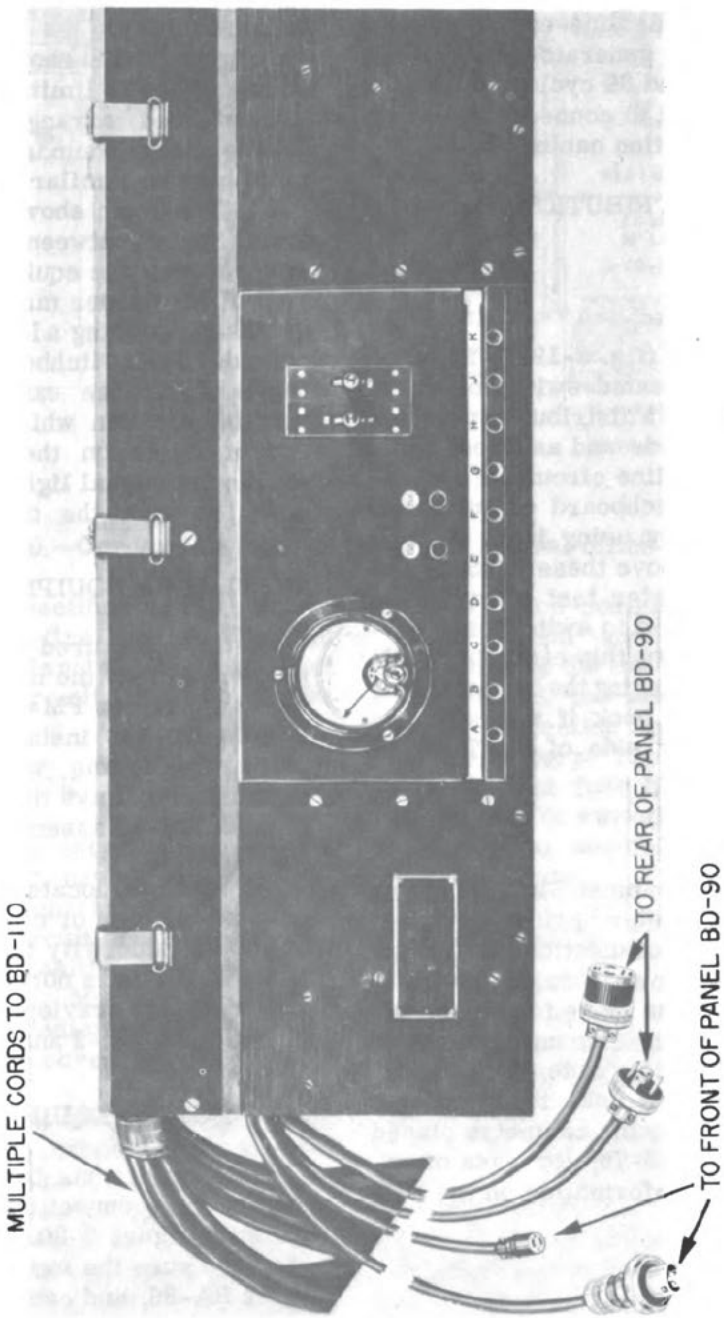


Figure 8-19.—Cabinet BE-72, front view.

110-to 120-volt, 60-cycle alternating current. A 50-foot cord CD-393 is provided to connect a 110-volt outlet to the a-c distribution cabinet BE-75. When commercial power is not available, two power units PE-75, included with the set, can be used to furnish the power. Each of these units consists of a gasoline-engine coupled to an a-c generator. This generator will deliver 2500 watts at 120 volts and 60 cycles. A 50-foot cord CD-409 is provided to connect power unit PE-75 to the a-c distribution cabinet BE-75.

TEST AND POWER DISTRIBUTION EQUIPMENT

Cabinet BE-72

Is use, cabinet BE-72 (fig. 8-19) is mounted on top of a centrally located switchboard. In this position, it serves as a distribution point for the power and alarm leads and as a test panel for the cord circuits and line circuits of switchboard BD-110. The switchboard circuits may be given routine tests by using jacks A to J. The equipment located above these jacks is associated with the voltmeter test circuit. The lines and trunks connected to switchboard BD-110 may be tested by using this circuit. An additional feature permits ringing the bells on a line having a receiver of the hook if the bells are connected between either side of the line and ground.

Cabinet BE-70

The wire chief's test cabinet BE-70 contains a 100,000-ohm, d-c voltmeter having a range of 0-40 volts with keys and connections which enable the testman to test for and locate practically all line faults. Provision is made for connecting a Wheatstone bridge to the line under test, for talking and ringing on the line under test, and for talking on call wires or trunks to operators, testmen, and so on. In use, the cabinet is placed on top of packing case GS-70, for ease of operation. (For additional information on the BE-70, refer to TM 11-345.)

LOCATION

Telephone central office set TC-10 should be installed in a protective enclosure. In humid climate, choose as dry a location as possible. In dry desert country, or in cold climates the ground is frozen to considerable depth, choose a location near a good source of ground if possible. The equipment may be located as desired, with the limitations as shown in figure 8-20.

The batteries and power units PE-75 should be installed in an enclosure separate from the switchboard to keep the switchboard room reasonably quiet and free from battery fumes and exhaust fumes.

Figure 8-21 shows a suggested floor plan where space is limited. Figure 8-22 illustrates a preferred arrangement using two rooms. Where a large room is available, the set arrangement may be similar to the setup shown in figure 8-23. The room shown is approximately 25 feet long. Space between the different components and between the equipment and the walls is essential for proper maintenance.

When choosing a location for the switchboard, consider the switchboard operator. Best operator performance can be obtained in a well-ventilated room which is not brightly lighted. Bright lights on the face of the switchboard makes the signal lights hard to see. Keep noise down so that the operator can easily hear.

SETTING UP EQUIPMENT

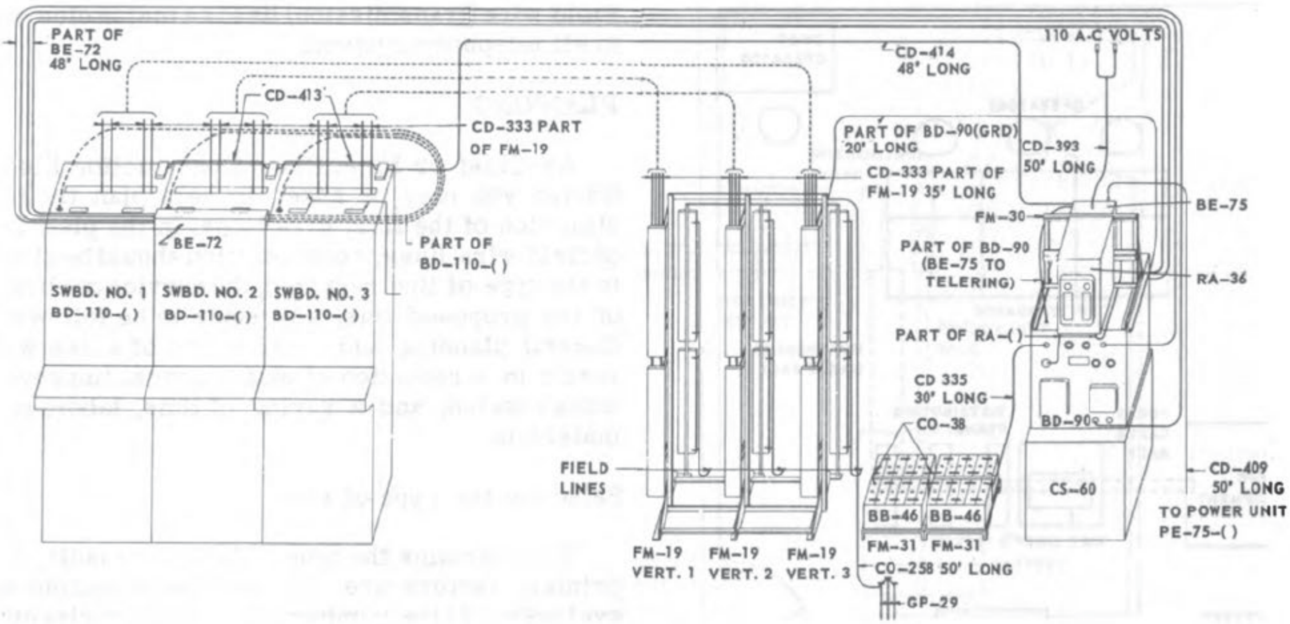
Set the required number of switchboards in place and erect the main distributing frame. Use as many frames FM-19 as the number of switchboards BD-110 installed. Then properly set in place the frame which will be nearest the switchboard. Have the small parts and adjacent frames FM-19 assembled in the order shown in figure 8-24.

If possible, locate a good ground source such as a water pipe or other buried metallic object of good conductivity having a large area of earth contact. If this is not possible, place ground rods as mentioned previously in setting up telephone central sets TC-2 and TC-4.

CONNECTING EQUIPMENT

All connections between units of equipment, except the connections to cabinet BE-70, are shown in figure 8-20. Before any connections are made be sure the switches on panel BD-90 rectifier RA-36, and cabinet BE-75 are in the OFF position.

One of the final operations will be to connect the four storage batteries BB-46 in series, using cords CO-38, to form a 48-volt group. Connect the battery to the BAT CABLE outlet of panel BD-90 using cord CD-335.



26.122

Figure 8-20.—Cording diagram of telephone central office set TC-10.

CAUTION: Poor connections at the battery, liable to arcing, are a fire hazard. When an outside source of power is not available, connect cord CD-409 from power unit PE-75 to cabinet BE-75.

PREOPERATIONAL CHECK

After your crew has set up the telephone central office set TC-10, have them make the following preoperational check;

1. Place the MAIN circuit breaker switch of panel BD-90 to the ON position. The voltmeter must read approximately 50 volts. A reading much different than this indicates wrong battery connections and must be corrected before proceeding.

2. Operate the switch of cabinet BE-75 to connect the power to rectifier RA-36. Set the rectifier coarse adjustment plugs to holes No. 8. Make sure that neither fine adjustment (lower) plug is inserted. Then operate the switch on the rectifier to the ON position. If both bulbs light, insert the fine adjustment plugs into the holes marked LOW. The ammeter on panel BD-90 should show a small current in the charge direction.

3. Operate the G key on the rear of panel BD-90 to the TEL position. The no-voltage alarm buzzer will sound. Operate the switch of cabinet BE-75 which controls the telering ringer. The alarm buzzer should stop, indicating proper operation of the telering.

4. Check the fuse alarm circuit by temporarily connecting the alarm stud of a fuse block to the battery. The fuse alarm buzzer should sound. Test fuse blocks on the rear of panel BD-90 and of switchboard BD-110.

5. When possible, test the cord, line, and trunk circuits.

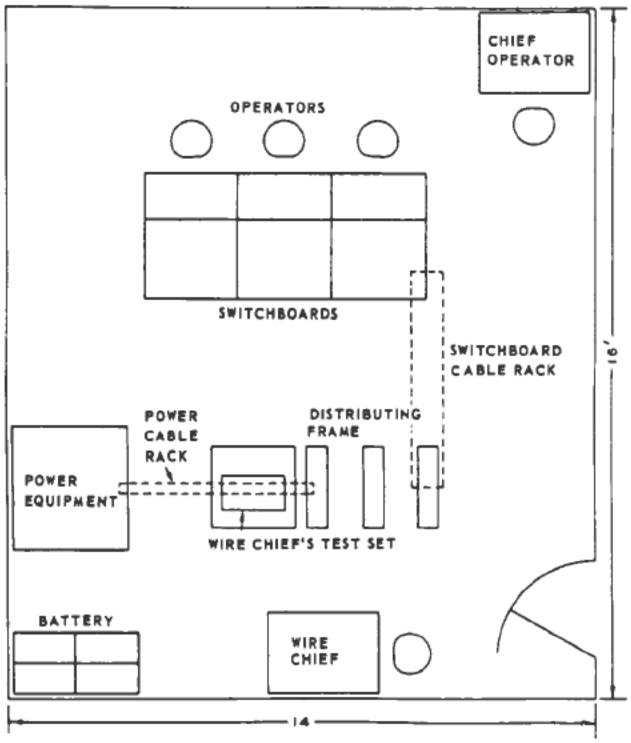
MAINTENANCE

Maintenance procedure for the TC-10 will be similar to that of the TC-2. However, as the supervisor, you should make up a routine maintenance check sheet and see that it is followed.

TRANSPORTABLE FIELD TELEPHONE EXCHANGE

The AN/TTC-7 is a complete, transportable, three-position multiple field telephone exchange, designed for rapid installation. It can handle local or common battery lines.

This equipment consists essentially of three, two-panel manual switchboards (SB-249 as shown in fig. 8-25) connected in multiple, each board with a maximum capacity of 200 lines and 20 trunks. It includes power and accessory components.



26.123
Figure 8-21.—Suggested floor plan for telephone central office set TC-10 in one room.

Each position is equipped with 15 cord circuits, thus giving a maximum capacity of 45 simultaneous calls. The face equipment of each position is wired to accomodate 500 lines and 80 trunks. For each additional 200 lines, three more switchboard positions are required.

To handle more than 400 lines, multiplying on a four-panel basis is recommended; in this manner the exchange may be expanded to accommodate 1000 lines and 160 trunks.

The AN/TCC-7 has a minimum of three switchboard positions but it is expandable in multiples of 3 or 4. The ringing circuit is rated at 20 cps at 90 volts. The power requirement is 110-v a-c; 48-v d-c. For additional information refer to TM 11-2146.

OUTSIDE TELEPHONE PLANT SYSTEMS

The preceding paragraphs discussed the various types of advance base telephone central office sets. Telephone sets, switchboards, and their components were explained in detail, but nothing was said about the outside plant system. Field wire (transmission) line is a major element in all telephone systems.

PLANNING

As Chief or First Class Construction Electrician you may be asked to help plan the installation of the field wire lines. In the planning of field wire lines, consideration should be given to the type of line required, the service qualities of the proposed line, and route to be followed. Careful planning and construction of a line will result in a reduction of maintenance, improved transmission, and a saving of time, labor, and materials.

Selecting the Type of Line

To determine the type of line to be built, the primary factors are: (1) the type of equipment available, (2) the number and quality of circuits required, (3) the length of the line, and (4) the time available for installation.

Service Qualities

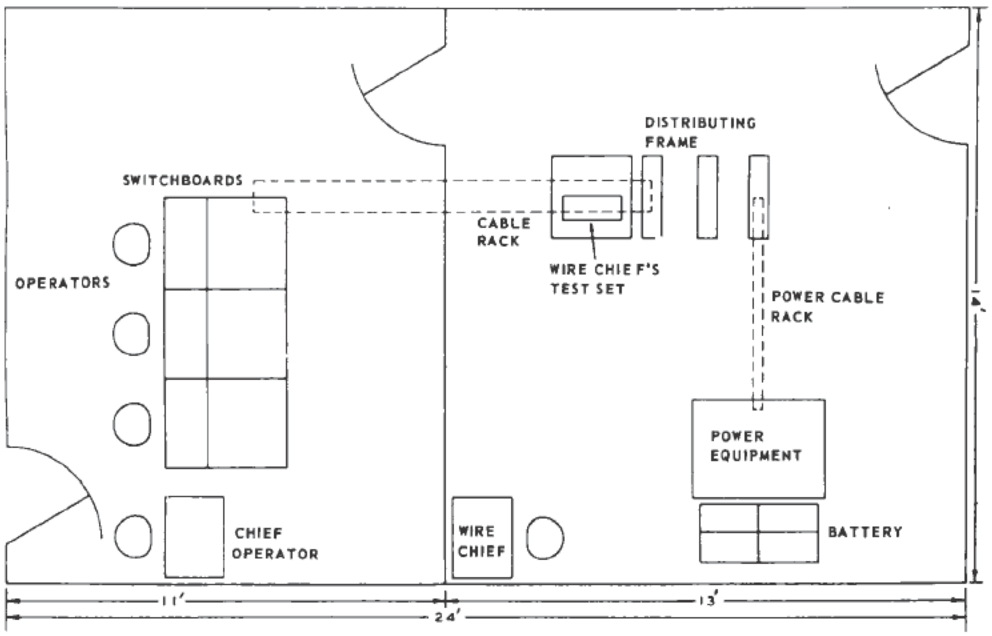
To estimate the service qualities of the proposed line, consideration should be given to the relative transmission characteristics of the different types of field wire when laid on the ground, when buried, or when installed on overhead supports.

Overhead lines, in general, give longer transmission ranges and provide greater physical protection for the circuit than other types of construction.

In surface-line construction, reliability is directly proportionate to the care and skill exercised in installation. Surface lines laid carefully, with consideration to ties, road crossings, and other means of protection, provide a reliable type of line suitable for certain advanced base requirements. On the other hand, wire lines laid rapidly on the ground without regard for policing require immediate and continuous maintenance, and are justifiable usually ONLY under EMERGENCY conditions.

Selection of Route

When the line is planned, the shortest and most effective route should be selected to allow construction with a minimum of time and materials. Factors that should be considered are the availability of materials, equipment, and



26.124

Figure 8-22.—Suggested floor plan for telephone central office set TC-10 in two rooms.

construction personnel; traffic requirements; specific requirements for the line; and the terrain, which should include a study of the map of the area, supplemented by ground reconnaissance. Difficult terrain should be avoided to reduce the need for special construction and to reduce the loss in speed and efficiency.

Continuous liaison should be maintained with all units engaged in road building and road improvement to avoid routing lines where there is a possibility of damage to the line from road construction. If wire lines must be laid along roads where construction work is being done, maintain coordination with construction units to guard against unnecessary interruption to wire communication. Where there is a possibility that the initial type of installation will be replaced by a more permanent type or where the lines may be used again by the same unit or another unit in the event of a move, choose the route that will make the change as easy as possible. Whereever possible, avoid compact or built-up residential areas. Wire facilities are difficult to install and maintain in congested areas. Use a cross-country route whenever practicable. Before the wire lines are laid, you, as construction chief, should reconnoiter the route.

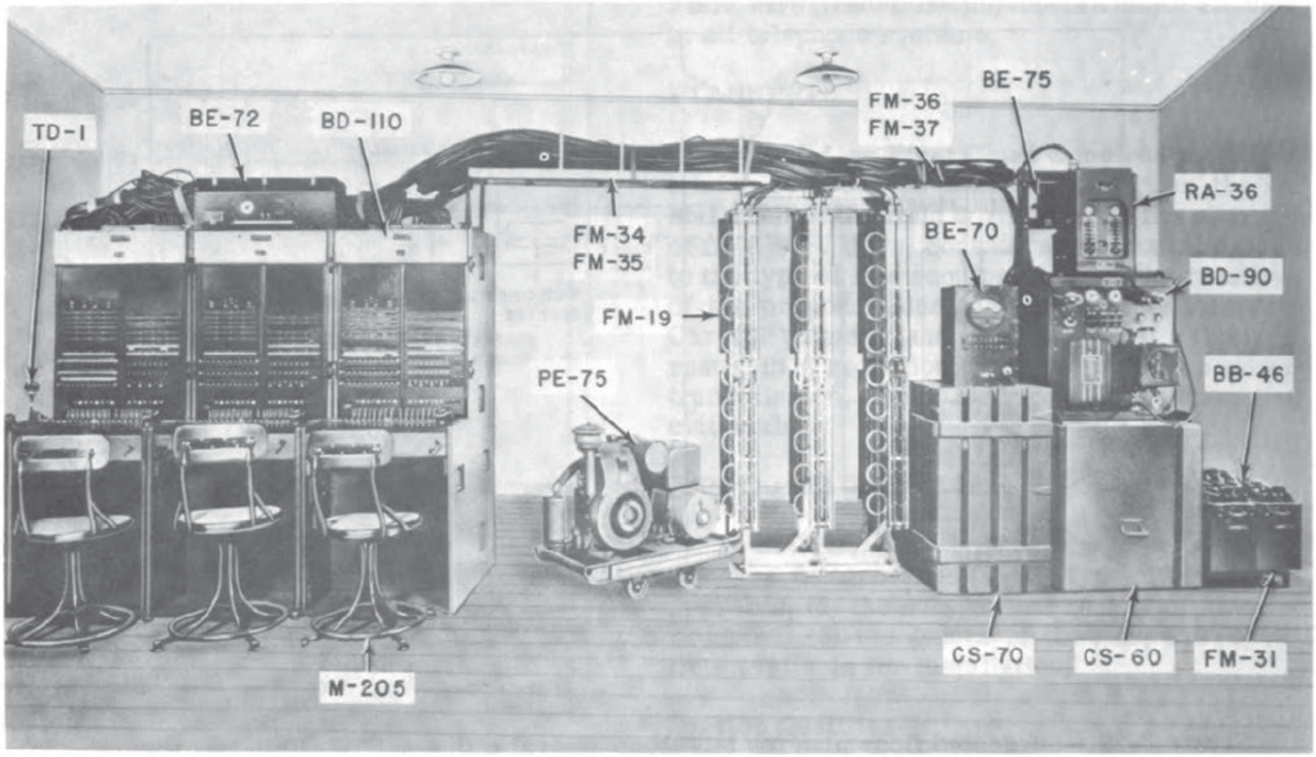
Before you get started on the construction, you should look for the following features along the route:

1. Number of overhead crossings
2. Number of underground crossings
3. Number of railroad crossings
4. Type of terrain and the type of construction best adapted to available wire-laying equipment
5. Number of stream crossings
6. Distance in miles
7. Any obstacles to maintenance

The next step is to select and mark clearly on a map the exact route along which the wire is to be laid. If no map is available, sketch a map of the area using some identifying objects along the route.

SURFACE-LINE CONSTRUCTION

Surface-line construction has two principal advantages: (1) A minimum of time is required for installation, and (2) loosely laid wires are less vulnerable to bombing than other types of construction. The two main disadvantages are: (1) Surface lines may become unserviceable in wet weather as a result of leakage to the ground, and (2) surface lines may be easily broken by the movement of personnel and vehicles.



26.125

Figure 8-23.—Telephone central office set TC-10 assembled.

In setting up surface-line construction, you should instruct your crew to proceed as follows:

1. Before starting construction, test the wire for the circuits to assure the continuity of each reel. Reels of wire that do not show a continuous circuit when tested are not used until the wire has been serviced.

2. At the starting point, tag the free end of the wire with the circuit designation. Place this tag 1 foot from the end of the wire.

3. Leave enough wire at the free end to reach the switchboard terminal strip or other installation, and tie the wire into some fixed object.

4. Connect the free end of the wire to the construction center terminal strip when one has been installed, to the switchboard terminal strip or to a telephone set.

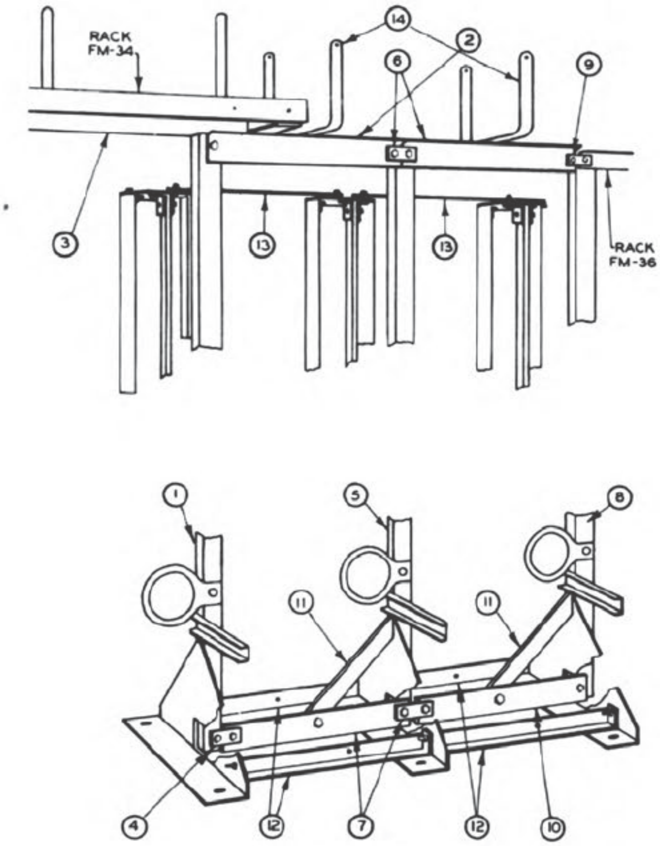
5. After each splice is completed, test back to the starting point from the far side of the splice to assure continuity of the circuit. To avoid making pinholes in the wire insulation from test clips, test the bare wires from the far side of the splice before taping is started. During the taping process, be careful not to cause circuit trouble. When connections are made at terminal strips, make a test from the far side of the connection back to the starting point. All circuits should be tested before they are reported.

Test Stations

To facilitate the testing and rearranging of circuits, test stations should be installed on a wire line. Test stations may be located at points where circuits diverge, at the end of a wire line that does not terminate in a switchboard, near points where circuits are most exposed to damage, at probable future locations of expansion, or at other convenient points on the line. When a unit is located where a test station has previously been installed, the test station can be converted easily into a telephone central.

Connections Between Surface Lines and Pole Lines

Connections between surface lines and pole lines are made most conveniently at established

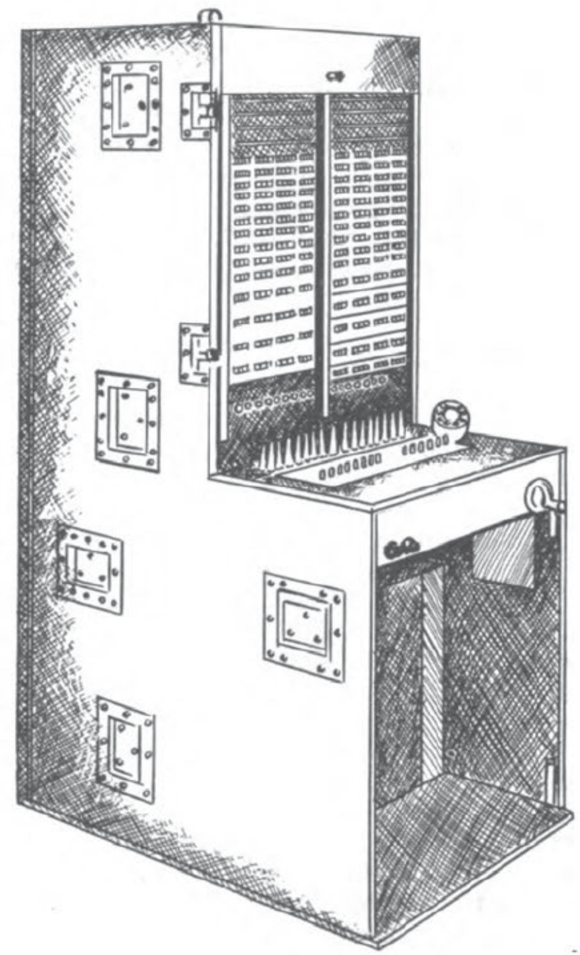


26.126
Figure 8-24.—Distributing frame, assembly diagram.

terminals or test stations. Whenever such connections are made, tie the surface line securely and tag it at the base of the pole at which the connection is made, then tie the line again just above the crossarm or terminal where the lines connect.

AERIAL CONSTRUCTION

A line attached to trees or other supports to provide the necessary clearance from the ground surface constitutes an aerial line. Cable that is intended to be laid directly on the ground but that is casually supported by underbrush or thickets is classified as ground-surface construction. The aerial construction method and techniques will not be discussed in this manual (discussed in CE 3&2). However, you are responsible for supervising the installation of serial lines on poles, trees, or 4 x 4 sawed lumber or equivalent.



26.193
Figure 8-25.—Switchboard SB-249.

DIAL TELEPHONE SYSTEM

It is not the intent of this manual to cover the dial telephone system in its entirety, but to discuss some of the fundamentals dealing with the central office building requirements, automatic functions, trunking equipment, the attendant's switchboard, test desk, main distributing frame, and the power, alarm, and metering equipment.

When you are assigned a project of installing a dial telephone system, you will receive a number of manufacturer's drawings showing cabling, system schematics, supervisory circuits, equipment locations, and interconnections. You should become thoroughly familiar with these plans so you can properly supervise the operation of your crew.

CENTRAL OFFICE BUILDING REQUIREMENTS

The site selected for a dial central office building should be slightly higher than its surroundings to ensure adequate drainage. Avoid low-lying sites which are likely to flood or remain excessively damp after heavy storms. In areas with heavy prevailing rainfall and poor natural drainage, the main floor of the building must be well above ground, and must be protected by earthworks and ditches.

Space Requirement

The building should be of such size and shape that the various units of equipment can be located for most efficient operation and maintenance.

If the central office is to include an attendant's switchboard for the manual servicing of certain calls, the switchboard should be installed in a separate room. This will help to isolate the operators from the noise made by the stepping switches.

The switching equipment and the power equipment may be installed in one room. It is desirable, however, to install the switching equipment in a separate room to minimize preventive maintenance. The central office battery is often installed in a separate, ventilated room, as close to the power board as possible. Modern sealed-type wet cells may be installed in the switchroom proper. If this is done, however, the room should be air-conditioned.

Floor Loading

Generally you will not be concerned about the floor load of any new structure for housing dial telephone system equipment. If the system is to be located in an old building, the floor joists and support should be carefully inspected. If you feel that you are not qualified to make the inspection, you should check with the Chief Builder or some other competent personnel to ensure adequate safety of the floor. If repairs are necessary, they should be completed before moving the equipment into the building.

External Power Source

AN ADEQUATE SOURCE OF THREE-PHASE, 220-VOLT, 60-CYCLE POWER MUST BE AVAILABLE for dial systems. If power source is not available, be sure that it is provided, before any communication equipment is installed. Also see that adequate lighting is provided.

AUTOMATIC FUNCTION

The central office equipment required to establish automatically a connection between two telephones is known as a link. The simplest link exists in an exchange servicing less than 100 telephones. This link is made up of two elements, a linefinder and a connector. In an exchange serving more than 100 lines and less than 1000 lines, a link consists of a linefinder, a selector, and a connector. In an exchange of more 1000 lines and less than 10,000 lines, a link consists of a linefinder, a first selector, a second selector, and a connector.

The equipment required to establish automatically a connection between two telephones served by a 100-line system consists of telephone lines connecting the telephones with the exchange, line equipment relays, a linefinder, and a connector.

Each telephone has its own individual line, consisting of two metallic wires that connect it to the central office. These wires may be strung with others on crossarms of poles, or they may be a pair of wires in an aerial cable or an underground cable. The telephone lines are connected to the inside equipment through the main distributing frame.

Each line served by the exchange is connected to line-equipment relays. When the handset of a calling telephone is picked up, the line-equipment relays actuate linefinder guard-circuit relays to seize an available linefinder. Another function of the line-equipment relays is to busy out the line (make the line unavailable for other calls) while the telephone is being used.

All the linefinders that serve a group of telephones are controlled by a guard circuit. The relays of the guard circuit, actuated by the line-equipment relays, function to seize an available linefinder. Tens and units relays in the linefinder, corresponding to the tens and units digits of the calling telephone, operate to extend the call to an available connector. The guard circuit prevents seizure of a linefinder by more than one telephone line if two or more handsets are picked up simultaneously. After causing a linefinder to be seized, the guard-circuit relays drop out of the circuit to become available for another call.

When a line is extended to a linefinder, the connector control relays are actuated to seize an available connector. Dialing the first digit of the called telephone causes the proper connector tens relay to operate. Dialing the second digit causes the desired connector units relay to operate, thus completing the connection between the calling telephone and the called telephone.

Links are wired in parallel (multiple) to the telephone lines. This arrangement makes it possible for any one of the links to complete a connection from any calling telephone to any called telephone in the group. The number of links wired in parallel for the group is based on the expected calling rate or the number of simultaneous calls, because one link is engaged for each talking connection. The lines from all telephones in the group are connected to both the linefinder and connector of a link.

Figure 8-26 shows how the talking connection is established through the linefinder and connector of a link. One wire is used to represent each line, and only 30 lines (three groups of 10) are shown to illustrate the principles involved. The wires for each group of 10 lines are connected to contacts of the linefinder tens relays and to the contacts of the connector tens relays. In both the line finder and the connector, there are 10 relays to accommodate 100 lines. These relays are numbered to correspond with the tens group of lines connected to the relays: F-10, F-20, and so on through F-00 in the linefinder; C-10, C-20, and so on through C-00 in the connector. The contacts of the linefinder tens relays, with identical units digits, are wired in parallel and are connected with the contacts of the correspondingly numbered units relays. For example, the contacts of tens relays F-15, F-25, and F-35 are wired in parallel and connected with the contacts of relay F-5; the contacts of ten relays F-41, F-61, and F-81 are wired in parallel and connected in parallel with the contacts of relay F-1. Similarly, in the connector, the tens relay contacts that have identical units numbers are wired together, in parallel, to the contacts of individual connector units relays numbered C-1, C-2 and so on through C-0.

When the handset of the calling telephone is lifted, the linefinder tens relay corresponding to the tens digit of the calling telephone operates, connecting all 10 lines of the group to their corresponding linefinder units relays. The units relay corresponding to the units number of the calling line then operates automatically and extends the calling line to the connector. The number of the called telephone must now be dialed to complete the connection. Dialing the tens digit causes a connector tens relay to operate, connecting its associated 10 lines to the connector units relays. Dialing the unit digit causes the operation of one of the units relays, and the talking connection is completed. For example, in a call from telephone 22 to telephone 34 (fig. 8-26), linefinder relays F-20 and F-2 operate automatically when the handset is lifted, to connect the calling telephone to the connector control relays. Dialing 34, the number of the called telephone, causes connector relays C-30 and C-4 to operate and complete the talking connection.

TRUNKING EQUIPMENT

Provisions are made in dial exchanges to permit the telephones served by the exchange to be connected with other exchanges. If the other exchange is automatic, the circuits that provide connections between the exchanges are called auto-to-auto trunks. If it is manually operated, the circuits that provide connections between the exchanges are called central office (city) trunks; the designation "city" is found on the exchange equipment, and usually indicates auto-to-manual trunks. Calls from attendant's switchboard (cabinet) to telephone users are made over circuits called out-dial (or local-dial) trunks.

Nondial telephones operating over common battery lines or over magneto lines may be served by a dial exchange. In such cases, the common battery and the magneto lines are connected with the attendant's switchboard of the dial exchange. Such arrangements permit the attendant to establish connections manually between the dial telephones of the exchange and the nondial telephones connected with it.

In most dial exchanges, dialing the digit 0 connects the telephone with the attendant's switchboard. Similarly, dialing digit 9 connects the telephone with a distant manually operated exchange, and dialing digit 8 connects the calling telephone with a distant automatic exchange.

The term attendant's switchboard is the official terminology for the equipment often described by telephone personnel and in manufacturers' specifications and drawings as the attendant's cabinet. Such a switchboard may consist of one or several complete switchboard sections or positions, depending on the size of

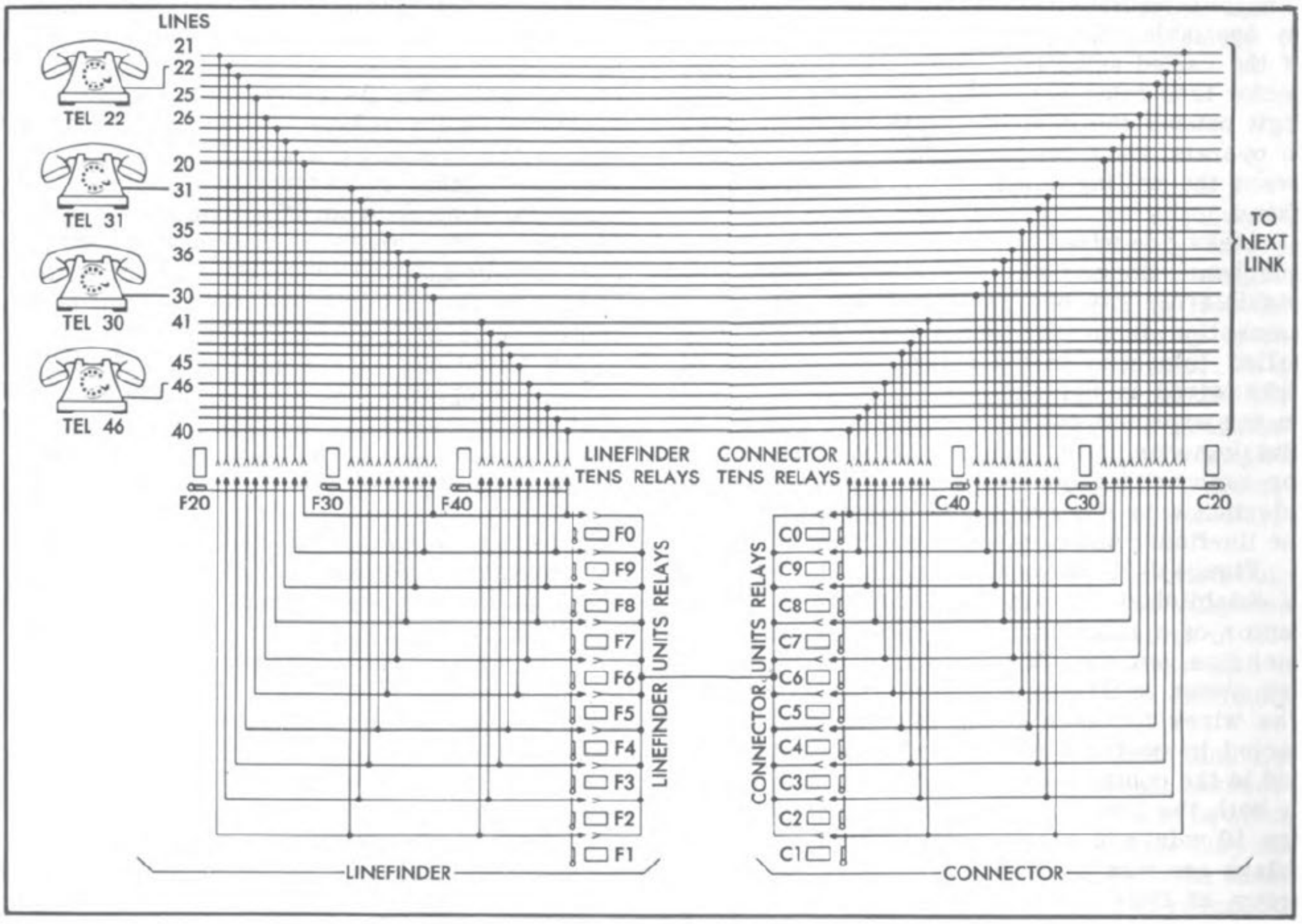


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Figure 8-26.—Simplified schematic diagram of link.

the exchange, the expected calling rate, and the types of service to be provided by the central office concerned.

ATTENDANT'S SWITCHBOARD (CABINET)

The attendant's switchboard provides facilities for an attendant to establish talking connections manually when they cannot be dialed, and also to furnish information. Calls to and from magneto and common battery lines can be handled at the attendant's cabinet. Information and out-dial trunks permit calls to and from the attendant, respectively. Central office trunks terminate at the attendant's cabinet and can be connected to any telephone served by the exchange. The attendant's switchboard is equipped with several cord circuits to establish the desired connections, and the attendant's telephone can be connected to these cord circuits.

Cord Circuit

A cord circuit is used by the attendant to interconnect circuits or trunks terminating at the attendant's cabinet. In addition, the attendant uses a cord circuit to initiate or to answer a call. The cord circuit is associated with equipment that also permits the attendant to dial. When a call has been terminated, the signal associated with the cord circuit notifies the attendant to disconnect the circuits.

Telephone Circuit

The attendant's telephone circuit enables the attendant to talk on any direct circuit

terminating at the attendant's cabinet. The circuit further provides talking battery and arrangements for connecting the attendant's headset to any cord circuit.

TEST DESK

The test desk is used to test outside plant facilities (line and telephones) served by the exchange. To test the quality and condition of the outside line, measurements are made of line resistance, and of line leak resistance between conductors and between conductors and ground. Other tests are made for foreign battery on the lines, proper connection of telephones, correct dial speed, and proper ringing of called telephones. Tests may be made from the test desk through a test connector, a test shoe, or test clips.

A test connector may be used to connect a particular line to the test desk. The test connector is first engaged and then, by dialing the last two digits of the desired telephone, a line is connected to the test desk to that tests can be made.

The line to be tested may be connected to the test desk by a cord that terminates in a test shoe or in test clips. These clips are attached to the line at the main distributing frame.

When a handset is not replaced on the hookswitch of a telephone, a howler tone may be connected to the line at the test desk. The receiver then emits a howl to call attention to the need of replacing the handset. A switch in the test desk is used to connect the howler equipment to any desired line through a test connector.

MAIN DISTRIBUTING FRAME

The main distributing frame serves two functions, (1) to connect the inside equipment with the outside lines, and (2) to interconnect various units of the inside equipment.

The outside-line wires normally are terminated on protector terminals on what usually is referred to as the vertical side of the MDF. The protectors protect the inside equipment to which the line is connected from high-voltage damage caused by lightning and from damage that might be caused by lower, but harmful, foreign voltages. Such voltages may be introduced by contact between telephone lines and power lines.

The cables from the inside-line equipment normally are terminated on what usually is referred to as the horizontal side of the MDF.

The line wires on the vertical side of the frame are connected to the inside-line equipment on the horizontal side of the frame by cross-connection wires (jumpers). These jumpers connect the line terminals to the terminals of the inside equipment required for a particular line or service.

The terminal blocks on the horizontal side of the MDF may be used to make semipermanent connections between units in the exchange.

POWER, ALARM, AND METERING EQUIPMENT

The power equipment is made of all the components necessary for the generation, storage, and control of energy for an automatic exchange. This equipment includes the motor-generator sets, the battery, the power panel, the alarm equipment, and the metering equipment.

Motor Generators

The dial exchange is equipped with two motor-generator sets. Each motor operates from a 220-volt, 60-cycle, three-phase supply, and each generator will supply a maximum of 25 amperes at a constant potential of 51.6 volts. Under normal or light load operating conditions, one motor-generator set will supply the d-c needed by the exchange, and enough to keep the exchange battery charged. Under heavy exchange load conditions, or when a battery is almost completely discharged, both motor-generator sets may be operated simultaneously.

Battery

The dial exchange is usually equipped with a 24-cell lead-acid type storage battery, which will furnish d-c for the exchange when the motor-generator sets are not in operation. The battery and the motor-generator sets are connected in parallel, so that any one of the three sources can supply the energy required to operate the exchange.

Power Panel

The power panel contains the control elements, fuses, and power meters related to the distribution of power to the units in the exchange.

Alarm Equipment

The alarm equipment provides a means of notifying the operating personnel of trouble in the system. The alarm lamps and buzzers mounted on the power panel operate when a fuse in any of the units of the exchange is blown. Each alarm lamp is labeled with the name of the unit it serves.

Metering Equipment

Several counter-type meters, labeled CALL and OVERLOAD, are mounted on or near the power panel. The call meters register the number of calls handled by various units of the exchange. The overload meter registers the number of times the various units in the exchange become overloaded (capacity exceeded by the traffic demand).

INTEROFFICE COMMUNICATIONS SYSTEMS

An interoffice communicating system is used to transmit orders and information among offices that are only a short distance apart. Frequently such offices are in the same building. Intercoms are not used at all advanced bases; if they are used, and there is no I.C. Electrician attached to the base, the job of installing, maintaining, and repairing them usually falls to the CE.

Assembling an intercom set requires considerable knowledge of the principles of electronics. For this reason, intercom sets intended for use at advanced bases are packed ready for operation. By observing a few simple rules and following the wiring diagram (fig. 8-27) that accompanies the set, you should be able to make the installation without difficulty.

An intercommunicating system consists of one or more master stations, a junction box, one or more remote speaker units, and the wire necessary to make the connections. One type of intercom set used by the Seabees is shown in figure 8-28. The master station (chassis shown in fig. 8-29) has a capacity of 12 remote speaker-microphone units; however, if one or more of the remote units are master stations or if one or more of the remote units are connected to the call-in circuit, the capacity of the system is only 11 remote stations.

The basic parts of the master station consist of a 3-tube chasis, a speaker-microphone, and a selector switch panel. The parts are installed in a wooden cabinet. A combination volume control and ON-OFF switch is mounted directly below the selector switch panel. The pilot light is illuminated at all times when the switch is on. A 3-position switch at the center of the cabinet front controls talk-listen or idle position. The speaker microphone is mounted inside the cabinet behind the grill on the front panel. A junction box, used for interconnection to remote stations is attached to the chasis by flexible cable. An a-c power cord is attached to the chassis.

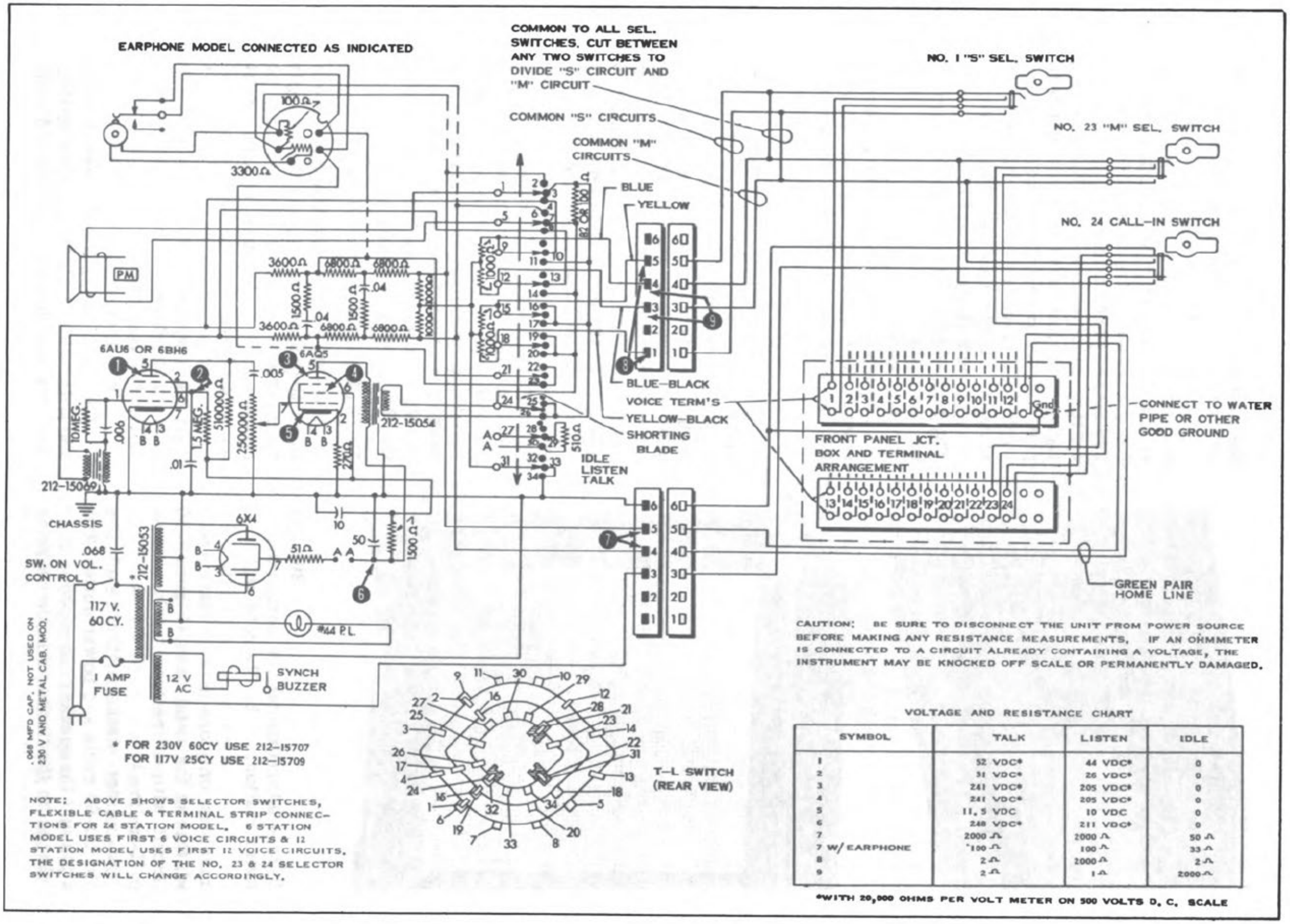
The switch panel consists of the selector switches (12 for the model shown), a space above each switch for identifying the station, and an annunciator for each switch. (All intercoms are not equipped with annunciators.) The switches have three positions: OFF, ON, and a third position to operate annunciators on a remote annunciator's master station unit.

The annunciators are solenoid plungers mounted above each station selector switch. When the button atop a remote speaker microphone is depressed, or when a switch on a remote master unit is pressed down, a buzzer at the master station sounds, and the annunciator above the switch for the calling station springs outward. The annunciator remains out until the call is answered; it should be pushed back to its normal position at the same time that the selector key is raised to answer the call.

The talk-listen lever is a 3-position switch. The three positions are IDLE, LISTEN, and TALK. Under normal operating conditions, the lever should be left in the idle position. The idle position should be used to determine whether a station to be called is in communication with another station. Leaving the lever in the idle position, flip the selector switch of the station that is to be called. If no other station is conversing with this station, press the lever to the talking position and speak into the master station. If the system has only one master unit, you may press the lever into the talk position without going through the idle position, since remote speaker microphone units cannot communicate with one another.

INSTALLATION PROCEDURES

Any combination of master stations and speaker microphone units up to the capacity of the master station can be used. Where it is not necessary for remote stations to communicate



VOLTAGE AND RESISTANCE CHART

SYMBOL	TALK	LISTEN	IDLE
1	52 VDC*	44 VDC*	0
2	31 VDC*	26 VDC*	0
3	241 VDC*	205 VDC*	0
4	241 VDC*	205 VDC*	0
5	11.5 VDC	10 VDC	0
6	248 VDC*	211 VDC*	0
7	2000 Ω	2000 Ω	50 Ω
7 W/ EARPHONE	100 Ω	100 Ω	33 Ω
8	2 Ω	2000 Ω	2 Ω
9	2 Ω	1 Ω	2000 Ω

*WITH 20,000 OHMS PER VOLT METER ON 500 VOLTS D. C. SCALE

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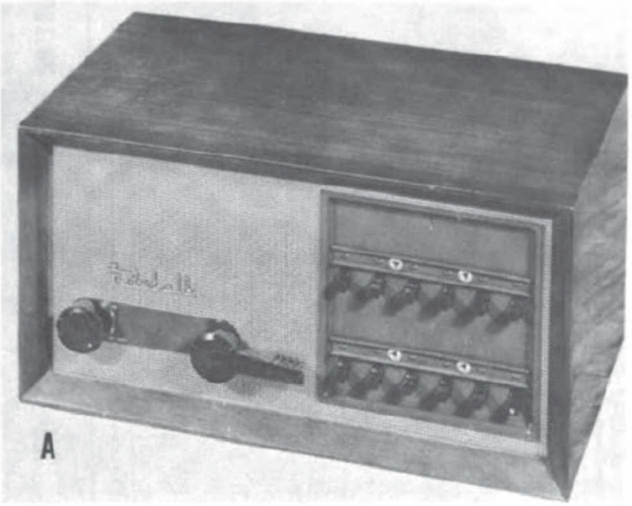
Figure 8-27.—Intercom model 700 wiring diagram.



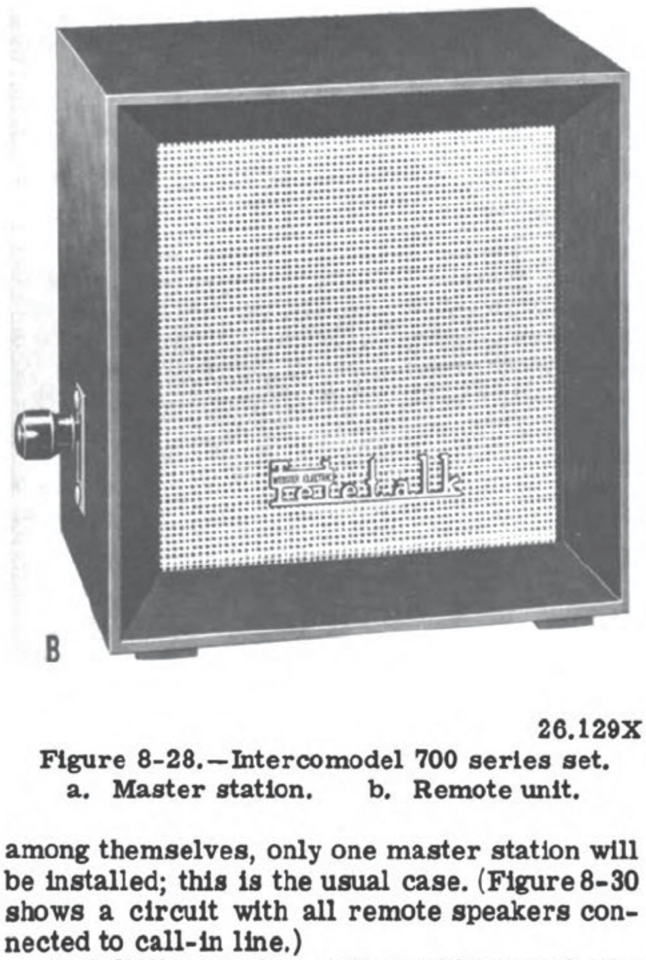


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Figure 8-28.—Intercomodel 700 series set.
a. Master station. b. Remote unit.

among themselves, only one master station will be installed; this is the usual case. (Figure 8-30 shows a circuit with all remote speakers connected to call-in line.)

Install the master station within reach of a 110-125 volt, 50-60 cycle a-c power outlet. The master station and the speaker microphone units should be placed on the desks or in the working spaces of the personnel who will use them. If some of the units are installed outdoors, take the necessary precautions to protect them from adverse weather conditions.

The size of the wires to be used in making connections between units is governed by the length of wire. For the voice lines, No. 22 to No. 19 twisted pair wire is used. The maximum wire resistance permissible will be stated in the operating instructions. For the model shown in figure 8-27, the maximum resistance is 50 ohms per pair. The amount of wire determines the wire size to be used. No. 22 wire gives a resistance of 32 ohms per 1000 feet, and No. 19 wire gives a resistance of 16 ohms per 1000 feet. The larger sizes of wire (lower number) should be used when great amounts are necessary to connect the units.

The wire resistance of the annunciator lines must be kept below 15 ohms per pair. Normally No. 14 wire (which gives 4 ohms per 1000 feet) or No. 16 wire (which gives 8 ohms per 1000 feet) is used.

All connections to a master station unit are made on the junction box; the wires are soldered to their respective terminals on the terminal strips. Connections to the speaker-microphone units are made by connecting the wires to terminal screws on the bottom of the unit. On models having annunciators, the annunciator wires are attached to the pushbutton terminal block.

Be sure that the interstation wires do not cross hot pipes. The wires should never be placed where they are in danger of being covered by water.

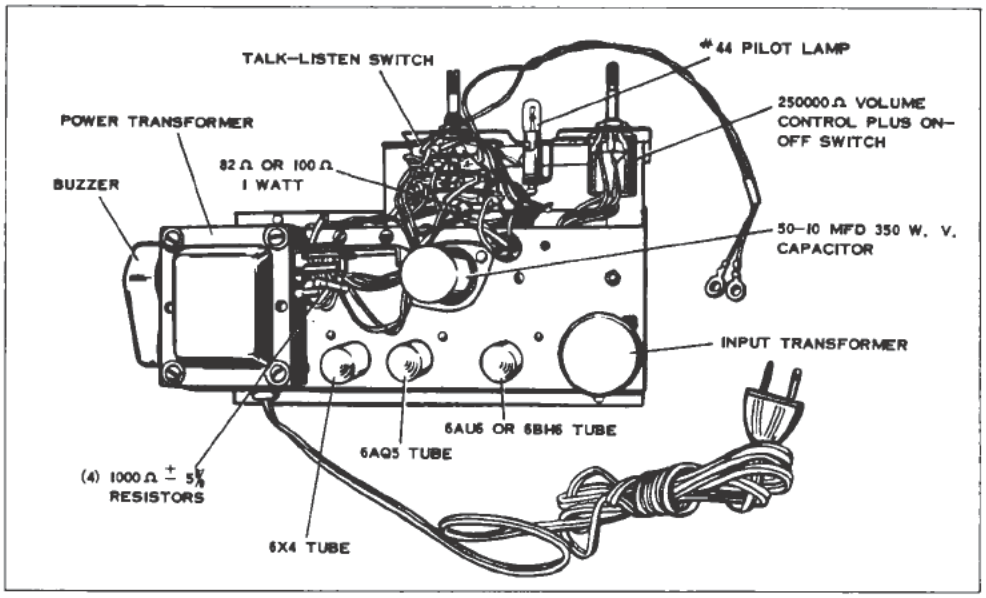
After the wiring is installed, check the resistance with an ohmmeter. Make certain that the maximum permissible resistance is not exceeded and that there are no opens, grounds, or shorts. (Note: Follow installation instructions that come with each new set.)

MAINTENANCE AND REPAIR

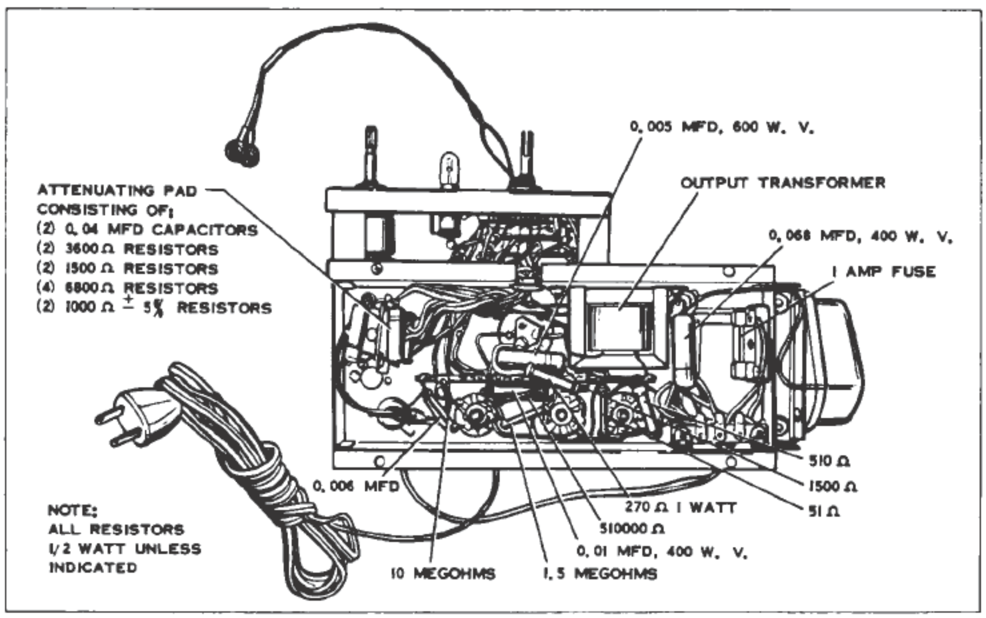
Many of the maintenance and repair instructions that apply to switchboards apply equally to intercom systems. In general, preventive maintenance techniques consist of five steps:

1. Look
2. Feel
3. Inspect
4. Tighten
5. Clean
6. Adjust

The feel operation is necessary to check and determine if electrical connections or bushings are overheated. Feeling indicates defects requiring corrections.



Top View of Chassis



Bottom View of Chassis

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Figure 8-29.—Chassis of a model 700 intercom master station.

Inspection is, of course, the most important operation in the preventive maintenance program. Check for the same four conditions that you check on a switchboard:

1. Overheating
2. Placement
3. Cleanliness
4. Tightness

The tightening, cleaning and adjusting operations are self-explanatory.

Table 8-2 lists the most common types of troubles that you are likely to encounter in an intercom set.

Components in intercom sets are readily accessible and may be easily replaced if found to be faulty. When a defective component such as a

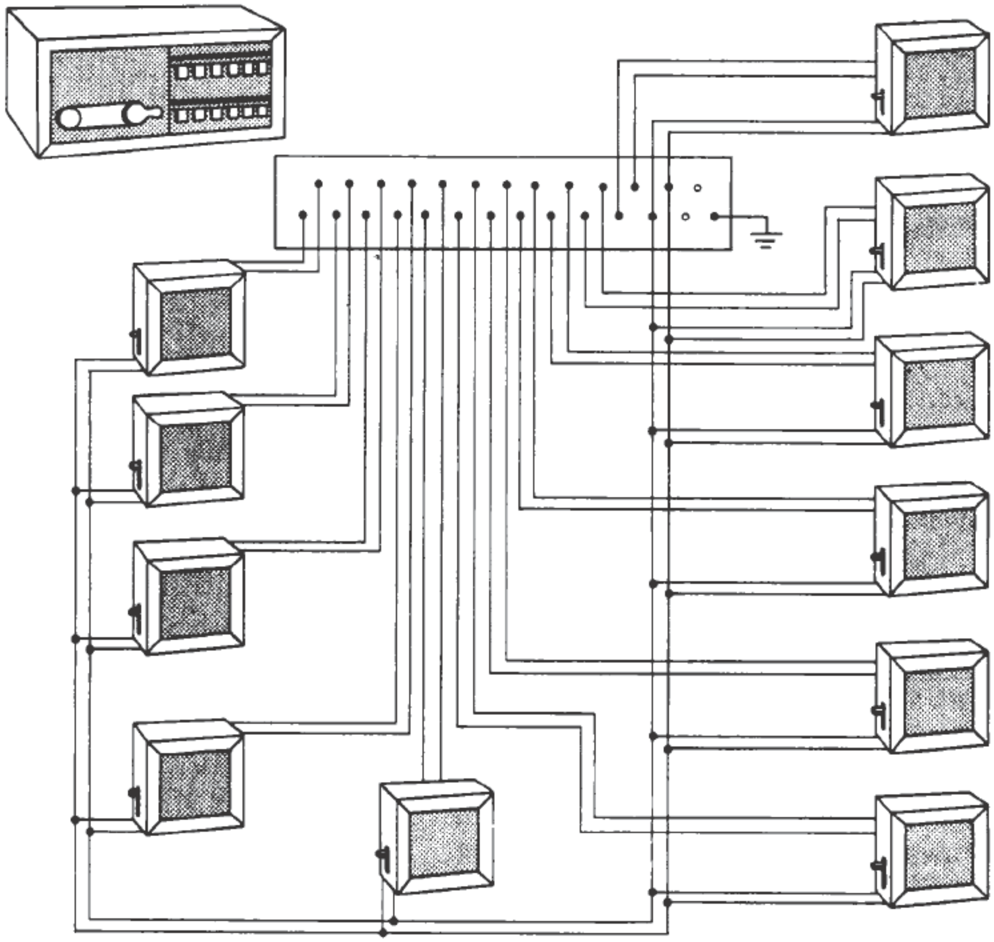

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Figure 8-30.—Twelve station intercom system layout.

burned-out resistor or transformer, is located, remember that the cause of the condition may be in some other part of the circuit. If the cause is not located and corrected, the new part will be burned out in the same way as the one that was replaced.

TROUBLESHOOTING

When trouble develops in an intercom system which has been properly installed and has been operating properly, the fault will usually be in one of the units of the system rather than in the interstation wiring. If the fault is in the interstation wiring it can easily be traced because the units will usually operate properly on some branches of the system. Once a fault has been been traced to some particular unit it can sometimes be located by sight or smell (burned out resistors and shorted transformers) but most faults must be traced by checking voltages and resistances.

In troubleshooting ALWAYS REMEMBER:

1. Noise or hum may be mechanical noises picked up by the microphone and amplified at the master station; or it may be caused by office equipment, or other external causes.
2. The majority of master station trouble can be traced to faulty tubes. Replace the tubes with a set of tubes known to be good before becoming involved in major troubleshooting procedures.

Before parts are unsoldered the position of the leads should be noted. If the part has several connections to it, each lead should be tagged. Care should be taken that other leads

Table 8-2.—Troubleshooting Chart for Intercom System

Trouble	Probable Cause	Remedy
1. Pilot lamp and tubes do not light when switch is on.	Power supply not on.	Test power supply.
	Defective switch on volume control.	Short out test.
	Poor connections in power supply.	Check circuit with ohmeter.
	Tube filament failure.	Check tubes.
2. Low volume and distortion.	Defective tube.	Replace with tube known to be good.
	Defective filter capacitor.	Replace filter capacitor.
3. Unit operates properly but with 60-cycle hum.	Defective tube	Replace with tube known to be good.
	Open or leaky filter capacitor.	Replace filter capacitor.
	Ground or lead in unit or in external wiring (hum occurs only when selector key is up).	Check from wire to chassis or ground with ohmmeter. Resistance should be over 100,000 ohms.
4. Pilot light operates and tubes light but unit does not operate.	Defective tubes.	Replace with tubes known to be good.
	"B" supply shorted or open.	Check circuits for open with ohmmeter.
	Open or shorted resistors.	Check all voltages.
	Loose or broken wiring.	Check by visual inspection.
5. Unit operates properly on some stations but not on others.	Open or short in interstation wiring.	Check interstation wiring with ohmmeter.
	Open contacts on selector switch	Check contacts on selector switches and clean with dry-cleaning solvent.
6. Feed back howl or hum.	Acoustical feed back from nearby unit.	Reduce volume.
	Input and output wiring too close.	Isolate circuits.
	Open filter capacitor.	Replace capacitor.

Table 8-2.—Troubleshooting Chart for Intercom System—(Continued)

Trouble	Probable Cause	Remedy
7. Distortion and low volume.	Open or leaky coupling capacitor.	Replace capacitor.
	Low "B" supply voltage.	Check supply voltage with voltmeter.
	Defective tube (exclusive of rectifier tube).	Replace with tube known to be good.
	Voice coil of speaker rubbing.	Replace speaker.

are not damaged by being pulled or pushed out of the way.

Remind your crew of the following facts when they are to solder connections:

1. A carelessly soldered connection may create a new fault.
2. A poorly soldered joint is a very difficult fault to locate.
3. It is easy to allow drops of solder to fall into the set.
4. Drops of solder in a set may cause a short circuit.

These points should particularly be remembered when leads are being soldered on intercoms. This information, however, applies to soldering of all communications equipment.

PUBLIC ADDRESS SYSTEMS

During the early stages of an invasion, portable types of public address systems are used to amplify speech in the landing area. Small types are d-c battery powered and are completely self-contained. When great sound coverage over a high level of noise is required, a larger a-c portable type, powered by a gasoline driven generator is used.

At an established base, a public address system may be used for an auditorium, outdoor movies, or for camp communications. A talk-back type of system can be used for camp communications. Horns serving as loudspeakers can be placed at strategic locations around the base.

The talk-back type is seldom used. The system generally used for advanced base communications is a portable set consisting of a 100-watt cabinet-type amplifier, a dynamic (movable coil) microphone with heavy-duty floor stand, two 25-foot lengths of shielded microphone cable, and one 25-foot length of heavy-duty power cable. This system requires 100/125 volts a-c on 50/60 cycles.

The horns serving as loud speakers can be controlled individually or in any combination. The speaker can address only one station, a few stations, or all stations. A change-over switch is provided to allow signal input from either a microphone or a phonograph.

As with any electrical circuit, the wiring diagram provides the key for the proper wiring connections. Normally, No. 14 size wire should be used for wiring connections. The horn loudspeakers may be mounted on top of buildings, on poles, on speaker stands, or even in trees. Before making the location of the loudspeakers permanent, it is desirable to test for uniform loudness, for minimum echo, and for dead spots. Follow the recommendations of the manufacturer closely when you make the installation.

Trouble in a p-a system is frequently caused by loose cable connections or breaks in the cable shield. Before commencing lengthy tests, check for faults of this type. In soldering connections make sure that both metals are clean; the completed soldering job should be firm and durable. Faulty soldering can cause faults in the system that are very difficult to locate.

Serious troubles in the system require signal tracing equipment such as an audio-signal generator and an output meter or an oscilloscope. In testing the electric circuit, the most important point to remember is that the trouble should be localized and isolated. A careful study of the circuit diagram will save much unnecessary testing.

CHAPTER 9

COLD WEATHER OPERATIONS

Electricity is required in polar regions for the operation of lights, power tools, communication equipment, certain galley and other appliances. In the polar facilities, electricity is also required for heating water and sewer lines. Because of the temperature extremes at the North and South Poles, the coverage in this chapter will relate to the camp facilities in those areas. This does not mean the coverage here could not be applied elsewhere in cold climates. The camp facilities in polar areas are advance base type facilities but they present design and specifications problems peculiar to this type of base.

POWER PLANT

Camp layout of cold weather advance bases usually calls for the utilities hut or building to be centrally located or as near the electrical load center as possible. The size of the power plant depends on requirements such as the number of men to be served, the load their equipment will draw and the mission of the base. Advance bases normally have a life expectancy of 2 to 5 years.

The required load for a 50 or 100 man camp is about 200 kw with a 50 percent standby power, therefore 300 kw is required. Power is supplied by three 100 kw diesel-electric generators. Two of the generators operate continously with the third used for standby power. For 150 to 200 man camps, additional 100-kw generator is added. Three 100-kw generators operate continuously, and one 100-kw generator serves as standby. Additional standby is provided by 10-kw generators located inside the furnace room in the service core of each building. Instead of providing emergency heaters for use when the main power plant fails or camp distribution lines are out, the 10-kw generators are provided to operate the forced-air furnaces and emergency lighting.

All generators are three-phase, four-wire, grounded-wye sets providing 120 and 208 volts. They operate at 1200 rpm with a power factor of 0.8. All components of a 100-kw unit are designed to permit parallel operation of up to four generators on a common switchboard bus.

PHYSICAL SUPPORT

The utility-storage building is a duplex consisting of two modified T-5s and an 8-foot passageway connecting the two buildings. The T-5 is an Army prefabricated arctic building. Figure 9-1 shows the floor plan of the modified T-5s. These buildings were designed to withstand a snow load of 50 pounds per square foot and a wind load of 100 miles per hour. The storage part of the building is one 28 by 52 foot room with an aisle through the center and storage shelves on either side. The utilities area is 28 feet by 68 feet where water production and power generation facilities are housed.

The foundation system consists of longitudinal beams supporting the ends of all floor panels and held in position by cross bracing. In the utilities building additional beams are used at the midspan of the floor units, providing an actual load-bearing capacity of 200 pounds per square foot. Open-web steel beams are used to lighten the system and to permit circulation of air under the building. The foundation is affected by the heat that the utilities building will produce, therefore, the foundation needs special consideration as to the type of material it is to be placed on. Snow, compacted snow, permafrost, ice, and possibly a gravel backfill area, are some of the types of materials the utilities building could be placed on. If the building were placed directly on the surface, the material would thaw and the building would settle; therefore, in all of these installations, there is an air space open to the outside

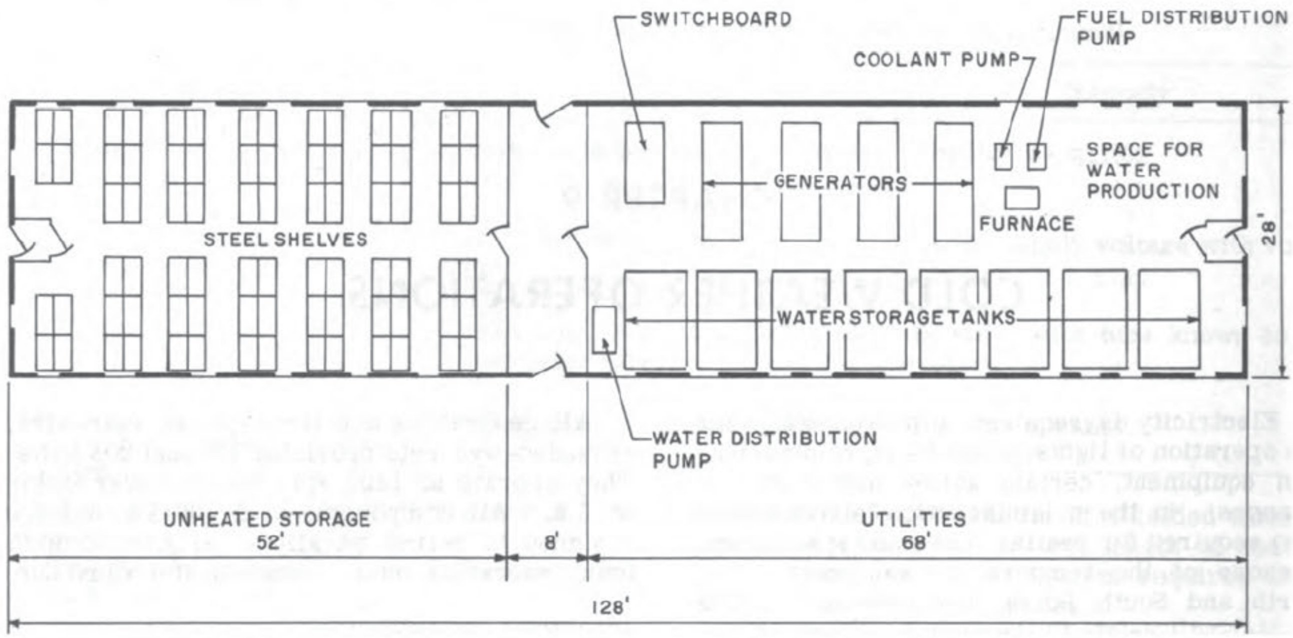

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Figure 9-1.—Utilities-storage building (T-5) floor plan.

atmosphere between the finished floor and the foundation. This space permits the dissipation of heat from the building. During operation of the power plant the foundation area should be checked to make sure it is not thawing and leading to a possible settling which could cause damage to the power plant.

LOAD CENTER

The utilities building is placed at the center of the camp and all other facilities are grouped around it in the most feasible pattern. This arrangement results in a compact camp with a minimum of utility distribution lines. The major consideration given to placement of buildings within the camp is grouping areas of like usage. The mess hall and galley complex is placed near the center of the camp for convenience of all personnel and because it is a prime user of water and electrical power.

INSTALLATION

The installation of the power plant is much the same as advanced base plants elsewhere. The difference is in parts of the switchboard and the grounding.

Switchboard

The switchboard is low-voltage, metal-enclosed switchgear and consists of a stationary structure assembly, removable main air circuit-breaker units fitted with disconnecting devices, and other necessary equipment. Fixed position feeder breakers and auxiliaries are parts of the makeup of this switchboard.

The switchgear handles 120/208 volts, three-phase, 4-wire service and has a tested dielectric strength of 600 volts. It meets the latest standards of the NIEE and NEMA. The cabinet is a self-contained housing with individual breaker and instrument compartments and a full height rear compartment for the bare buses. It has a small instrument panel hinged to the upper right end that contains certain meters. The individual circuit breaker compartments are equipped with primary and secondary contacts, rails, stationary disconnecting mechanism parts, and the cell interlock which prevents moving the removable unit into or out of the "connected" position while the breaker is closed. Each main circuit includes the necessary 400A bus and the connections between the main 1600A bus and one set of circuit breaker studs. The bus consists of high-conductivity bare bars mounted in heavy insulated supports.

The main bus joints and all tap connections are silver plated and tightly clamped with through bolts to ensure maximum conductivity. There are terminal blocks mounted to the top of the switchboard for secondary circuits.

The stationary part of the primary disconnecting devices for each circuit breaker is a set of contacts mounted on an insulating base. Buses and outgoing cable connections are directly connected to them. The corresponding moving contacts are a set of contact fingers suitably spaced on the circuit breaker studs. In the connected position, these contact fingers engage the stationary contacts, forming a current carrying bridge. The uniform pressure on each finger is maintained by individual short leaf springs and the assembly is full floating to provide ample flexibility between the stationary and moving contacts. A heavy duty finger type ground contact is mounted on the frame of the removable unit and a stationary ground contact of ample capacity is bolted to the ground bus. Each switchboard has interchangeable main circuit breakers and has a visible position indicator, mechanically connected to the circuit breaker mechanism so that the position of the breaker is indicated from the front door of the compartment. Manual tripping of the main breaker may be accomplished from the face of the switchboard compartment with the door closed.

Grounding

The grounding system cannot be overemphasized. Because of the lack of a good natural ground in areas where the camp is constructed over permafrost, snow, or ice, special care is required in installing the ground system.

In these areas, there is a ground grid installed at the power plant with connections from each transformer bank, building, fixture, outlet, etc., made and returned to the ground grid. If there is enough wire to install a separate ground do so. Another grounding procedure is to carefully balance the loads throughout the camp and use the neutral as the ground. When the location permits, a metal plate with a cable is attached, and dropped in the sea. This assembly could be added to the grid or used in place of the grid. Each location has its ground characteristics and the methods used for grounding will vary from location to location.

Spacing

There are general space requirements that have to be met when you are installing the equipment in the utility building. The spacing will have to allow for ease of operating the power plant. Have ample space for holding routine maintenance and overhaul of the plant machines such as engines, switchgear and related equipment.

PLANT OPERATIONS

The normal operation of the power plant has one generator idle for a standby. A base unit selector switch determines which unit will be the standby. In the event one of the generators fails to synchronize or if, with all except the standby generator on the bus, one generator is tripped due to reverse power operation, the standby generator will automatically start and synchronize to share the load with the remaining energized units. Power relays for each generator are provided so that as the load decreases the generators will shut down in sequence until only one generator is running to carry the light load. This generator is selected by the base unit selector switch.

As the load increases, generators will automatically start and synchronize until all the generators (except the standby unit) are on the line. When more generators are required to carry the load than are available, feeder breaker S-1 automatically opens and remains open until manually reclosed. If breaker S-1 opens and overload still exists, breaker S-4 will automatically open and remain open until manually reclosed. The plant can be manually, as well as automatically, synchronized. The voltage regulators have a sensitivity of +/- 1.5 percent. The remote alarm system will indicate when the automatic-manual switch is left in the manual position or test position. The alarm will indicate when the breaker S-1 or S-4 opens. The alarm is powered by a 24-volt plant battery and is actuated by auxiliary contacts on each of the various safety devices which are connected in parallel. This alarm is also actuated by prime-mover malfunctions.

SETTING THE WATCH

The watch on the power plant will be set as soon as the first generator is put into operation. The instructions that the watch standers

are to follow should be clear and understood by all the men standing watches in the plant. Chapter 6 of Construction Electrician 3 & 2, NavPers 10636-E, has good coverage on standing watch in the power plant and on the basic rules each watch stander should follow.

OPERATIONAL LOGS

The plant log serves as a basis for determining when equipment requires maintenance or replacement. A series of logs can often pinpoint signs of breakdown in various parts of the plant equipment—when the breakdown is taking place so slowly that on any one day it is not obvious as a problem in maintenance or repair.

Figure 9-2 illustrates one type of log that may be kept on the generator units of a power plant. However, since there is no standard form, the person in charge will draft one to fill the needs of the power plant.

MELTING SNOW

Melting snow is one of the methods used to furnish water needed to operate a camp located in a polar area. The generator exhaust is directed through a tank which contains clean snow. There are other means of melting snow, but this is a way to utilize the heat that otherwise would be wasted. The air flow through the radiator of each generator unit is used to heat the building in which the power plant is located. Because of the snow melting facilities being in the power plant, the plant watch standers will probably be required to operate the water making and water transfer equipment.

DISTRIBUTION

The basic factors that influence design of transmission lines and distribution systems in temperate climates are applicable also to the

SUGGESTED FORM OF PLANT OPERATION LOG

Date	Time	UNIT NO 1785			UNIT NO 942			UNIT NO 3465			REMARKS
		Elapsed Time Meter	Volts	Amperes	Elapsed Time Meter	Volts	Amperes	Elapsed Time Meter	Volts	Amperes	
4/17/59	1600	195.0	220	58	302.0	220	52	934.0	220	27	Started up
"	1730	196.5									added 2qts oil to #1785
"	2100	200.0	221	54	307.0	221	49				Shut down #3465

73.57

Figure 9-2.—Typical operators log.

design of such facilities in the polar regions. Electrical systems in these regions are usually not subjected to violent electrical disturbances and usually benefit by the close proximity of the generating facilities to the centers of load. They are subjected, however, to the environment of the area, which requires that special consideration be given to great variations in temperature, the performance of materials at extremely low temperatures, problems involved in the construction of overhead and underground facilities in ice, permafrost and deep snow, and the difficulties frequently incurred where the attainment of adequate electrical grounds is not economically feasible.

POLES AND POLE PLACEMENT

In general, all poles for use in the polar regions must be imported. Their selection as to type for wood and quality should be based on the expected permanency of the line. Butt-preservative treatment of the poles is required, but full-preservative treatment is generally unnecessary because decay processes in the aboveground portions of the pole will be relatively slow in the semiarid areas common to the polar regions. It is recommended that pole spacing within the station areas be limited to 100 feet. Pole-setting depth in ice or permafrost should be 5 feet for 35- and 40- foot poles, and should be increased 6 inches for each 5-foot increase in pole height. Poles supporting transformer platforms should be set to a minimum depth of 6 feet. Pole setting in the ice or permafrost may be accomplished by drilling with tungsten-carbide-tipped augers or blasting where permissible. The pole is placed in position, the hole backfilled with the materials from drilling or blasting and the area filled with water. The pole is supported until frozen in place.

Tripods have been used successfully for low-voltage distribution lines. These structures consist of three comparatively small poles so lashed together at their tops as to allow for slight movement. It is advisable to weight tripods with rocks or other material suspended from the structure or to pin each leg into the snow with a short section of pole bolted to each leg to help prevent overturning. The use of tripods should be limited to short lines of low voltage.

POLE LINE HARDWARE AND CROSSARMS

Conventional crossarms and pole hardware are used on pole lines in the polar regions just as in the temperate zones. In general, construction should be of rugged or heavy-duty type with heavier guy wire, anchor rods, anchors, strain insulators, and secondary racks in order to withstand tensions produced by high winds and extremely low temperatures.

INSULATORS FOR OVERHEAD LINES

All the common types of standoff and strain insulators designed for pole-line construction are satisfactory in their proper applications in the polar regions. The materials commonly used have excellent electrical and weathering properties and maintain good dimensional stability at extremely low temperatures. Care should be exercised in the storage and handling of insulators in extremely cold areas to prevent shock or sudden changes of temperature since this may cause some materials to shatter.

WIRE AND CABLE

Copper, copper-weld, and steel-core aluminum conductors are satisfactory in their proper applications in the polar regions. Selection of the type of conductor for each application should be made only after careful consideration of the temperature variation and wind velocity prevailing at the site, and the ultimate strength and sag characteristic of the materials. All wire for overhead lines should be stranded and polyethylene weatherproof jacketed. The minimum size should be No. 4 AWG medium-hard drawn copper, or equivalent in other materials listed above.

Aerial cables of the bundled or self-supporting types have some application in the polar regions where the temperature is not extreme. Because of the higher cost and the exacting insulation requirement caused by extreme cold and high-velocity winds, their general use cannot be justified.

Working with Wire

From the experience of the past years in extreme cold areas we have learned that most insulation breaks down from the cold. One suggested way of combating this is to heat the

cable rolls in some type of tent, room, etc. When the cable is warm, roll it out and hang it up while still warm or straight. When tapping splices or connections, plastic tape is likely to break down from a cold temperature. A possible solution is cloth tape and gum rubber where lower voltages prevail. Some of the various problems that you will encounter have been solved with common sense reasoning.

TRANSFORMERS

Conventional overhead-type transformers are satisfactory for use in the polar regions. The installation of three single-phase transformers on one pole should be limited to 25 kva size. For 37 1/2 kva size and larger, three single-phase transformers should be installed on a 2-pole platform. In general, transformers should be restricted to single phase to reduce size and weight of units for airshipment and handling.

UNDERGROUND SYSTEMS

Cable insulation shall conform to Specification MIL-C-13777C. Cables for installation in conduit systems in utilidors (an insulated utility trough), where provided in the polar regions, shall be in accordance with NavDocks Specification 9Y (latest revision).

Direct-burial cable up to 600 volts for installation in the snow should be 3-conductor polyethylene-insulated and jacketed. The cable should be unreeled and drop into the trench rather than pulled in from one end, in order to prevent strain. The cable should be installed a minimum of 18 inches under the surface of the summer snow line. The entire route of the cable should be marked with flags spaced not less than every 50 feet. Where cable passes under a runway or established route of hauling heavy loads, the cable should be placed in heavy wall fibre or transite conduit and the depth increased to 24 inches. Where possible, cable should be one piece. Where splices in the snow are necessary, split-cast iron splice boxes should be used. Upon completion of splices, the boxes should be bolted and filled with insulating compound.

Where cables above 600 volts are necessary, selection should be on the basis of flexibility of insulation and should be polyethylene jacketed. Installation depth should be not less than 30 inches based on the summer snow line. Installation and splicing should be as described above.

TRANSFORMERS

Transformers for underground vaults should be subway type. Where installed inside buildings, transformers may be askerel-filled or air-cooled type. Where installed remotely on platforms on the snow, transformers may be askerel-filled or air-cooled of the completely sealed or encapsulated type. A shelter should be provided as protection from drifting snow.

LIGHTNING PROTECTION

Lightning arresters are not generally used to protect transformers and other electrical apparatus in the polar areas because of the infrequency of natural electrical disturbances and the great difficulty in obtaining effective grounding. Where the frequency of such disturbances warrants protection, the protection can be provided only to the extent that grounding can be obtained. Where warranted, and a satisfactory ground can be obtained, protection can be provided in the conventional manner by the installation of lightning arresters for the protection of transformers and other apparatus on overhead transmission and distribution systems.

SAFETY SYSTEMS

Safety systems in polar regions are particularly important because of the remote location and extreme weather conditions. Polar camps are often located in areas which are totally inaccessible during certain seasons of the year for periods as long as 9 months. In case of disaster in such a location, no outside assistance can be obtained and injured personnel cannot be evacuated. The extreme weather conditions add to the hazard because loss of shelter or heat would be fatal. Fire alarms, firefighting equipment, and intercommunications for the camp are mandatory. The automatic fire alarm system used in these regions is the fixed-temperature type. It is reliable and simple in operation.

This device is available in both spot and line types. The spot type is better suited for the temporary polar camp because most of the buildings are partitioned into separate rooms. A detecting device should be placed in each room, and at several locations in large areas such as the recreation room and mess hall.

The detectors are connected to an alarm in the administration or communications area where someone is on duty at all times. In

addition, the system should sound an alarm in the building where the fire occurs to warn all personnel to evacuate the building. In some buildings there may be an Ansul compressed gas extinguisher system. The alarm for this system is much the same as the one mentioned before.

INTERCOMMUNICATIONS

Communications between buildings are essential for convenience in operation of the camp as well as for safety. A disaster can sometimes be averted by fast communications to give warning or to summon all available assistance. This system provides both communications between two points and also among all points for general camp announcements.

A dial telephone system with an automatic switchboard would eliminate the requirement for switchboard operation or the controlling of a master in a conventional intercom system. An automatic switchboard that has a 20- or 40-line system would be ideal. A paging adapter is available for the system. With this adapter, announcements can be made from any telephone over a public address system. Such a system will require installation of speakers in each building and possibly in outside areas if camp operations require it.

PERSONAL SAFETY PRECAUTIONS

There are many precautions each man should observe in cold regions and the following list includes some of the more important ones.

1. Frostbite—All precautions should be taken to avoid frostbite from the wind and cold. Use the buddy system to check each other's exposed skin areas when working outside where frostbite is possible.

a. When climbing poles take precautions that climbers do not cause frostbite through your clothes.

b. The wind is deceiving and a person can get frostbitten before he realizes it; check your exposed skin often.

c. If signs of frostbite should show on your buddy's face (for example), use your hands and his hands alternately, but DO NOT rub the affected areas. Warm your hands under your armpits, or crotch, etc., while he holds his hands on his face. When his hands are cold, place your hands on his face while he warms his hands. If it is his hands, feet, ears, etc., you and he should keep the exposed area as warm as you can and get medical attention as soon as possible.

2. Frozen tools or metal—Never handle frozen tools or metal with your bare hands.

a. Be careful while working with frozen tools; they are brittle and could easily break and cause injury.

3. Frozen poles—When climbing frozen poles make sure the gaffs are filed properly and you have applied enough pressure into the pole for the gaff to hold.

4. White outs—Do not go out during a white out unless it is absolutely necessary. If you do have to go out take all precautions prescribed by the officer in charge and any additional safety precautions necessary for the specific job. Remember that it's your life and the lives of your men which are involved.

5. Blowing snow—In some conditions, blowing snow can cause the loss of direction. A suggested way to stay alive is to use a dark object, tool, glove, etc.; place the object on the snow and walk around keeping it in sight, thus not completely losing your directional senses. By moving around you keep your body heat built up to keep from freezing to death. This suggestion could also work if you were caught in a white out.

CHAPTER 10

TRAINING

TRAINING RESPONSIBILITIES

Opportunities for conducting training are unlimited. Training includes all of those formal and informal situations where individuals or crews are given instruction toward the solution of:

1. Immediate problems related to the readiness of the unit to perform its current mission, or the problems related to the readiness of the members of the unit to do their jobs with a high degree of skill.
2. Long-range problems related to the readiness of members of the unit to qualify for advancement in rating, or the problems encountered when members of the unit need training for future jobs requiring skills not now possessed.

In most battalions, wherever problems are discovered, it has been found that many of them can be solved by training. Even so, training is not a wait and see responsibility. It must go on at all times. For example, training is conducted while your battalion is at the home port; and upon deployment, the embarkation and debarkation procedures are, for the most part, training exercises. Construction projects undertaken while deployed also have a valuable training function. All of this training serves a long-range preparedness need as well as the need for various skills on the immediate construction project.

IMMEDIATE AND LONG-RANGE PURPOSES OF TRAINING

Training men in advance of deployment to do a specific job has both immediate and long-range benefits. Advance planning sometimes provides for such training. For example, the detachment of Seabees assigned to Operation Deepfreeze II (Antarctic Operation) underwent a rigorous advance training program which included physical exercises, field marches, safety and survival lectures, and special schooling in coldweather work techniques.

A study of the job skills required to do a future job may be the starting point for training. After you have made such a study, take an inventory of the skills the men in your crew now possess. You can easily see whether the required skills match the available skills. When you cannot match the skills, you may have to conduct training sessions in order to bring the men up to the proficiency required to do the job. In some cases you will have to conduct refresher training; in other cases you will have to provide instruction in new techniques for doing things.

At the job site, for example, much of the training will be for the purpose of helping a man become more versatile, so that he can fill more than one job. One man might be an excellent splicer, but a poor mechanical and/or soldered electrical connections man. On the other hand, some of the training may be to help him do his present job better. To do your own job properly, you must study and work continuously to improve your own techniques. You must analyze work procedures and find ways to combine operations to shorten the time required to do a job. Having done this, you must train your men in the new procedure.

Some training that goes on in a battalion is of a general nature not related to the job at hand. Training for advancement in rating, including cross-training, is a good example of training of a general nature which obviously has long-range benefits.

ADMINISTRATIVE GUIDELINES

A majority of the men enlisting in the modern Navy will need technical or specialized training, owing to the great number and variety of highly

specialized mechanical and electronic devices employed in modern warfare; and it is likely that that need will increase.

From the standpoint of the individual, it is safe to say that the average newly enlisted man selected for specialized training has ambition and wants to advance in his Navy career. To this end he wants everything taught him to be practical. When these attitudes and preferences are coupled with the widely varied educational backgrounds of the men, it becomes apparent that the individual level of education is important to both the instructor and supervisor of the training program. The beginning level of each course of instruction must be adjusted, as nearly as possible, to the individual educational level because progress will depend to a large extent on each man's previous background.

In addition to the influences exerted by previous education, the progress of the trainee will depend markedly on his individual ability to learn. Psychologically, learning encompasses preception, the thought processes, and the motor functions. The operation of these factors results in the development of motor skills, the acquisition of knowledge, and the development of reasoning and judgment.

The Navy enlisted man is usually interested only in training that has a real, immediate objective. He is interested in information and learning, only insofar as he can see the attainment of a goal whereby he can advance himself in his own eyes and in the eyes of his shipmates, friends, and relatives. Consciously or unconsciously, the man will, from time to time, evaluate his progress in these terms, and the Navy training program must be able to supply the means for achieving this goal if training is to remain meaningful to him. Once the program has lost the immediate objective in the eyes of the man, his level of aspiration will decline. His motivation will also disappear, and with the loss of motivation he loses the prime mover in the whole process of learning.

Learning must take place in relation to what the student already knows; it must tie in with the whole and be considered a part of the context or entire pattern of the man's knowledge. It should result in his being able to use the new knowledge in a practical, working manner. Specific information given the learner should be supplemented by general inclusions allowing new information to be applied to other situations. Particularly is this principle true in adult education and in vocational training, both of which characterize the Navy training problem; the men have little interest in subject matter for which they cannot see an immediate, practical, and functional application. The new must be built into the old.

It is well known that social and physical environment exert a tremendous influence on the learning process. In addition to social pressures, it is obvious that personality factors and social relations in the learning group interact to form attitudes that may be either helpful or detrimental to the learning of the individual student. The resolving of problems in this area is to a great extent the responsibility of the instructor; teacher enthusiasm, initiative, and resourcefulness in human relationships are of the utmost importance to the learning process. Interest evinced in the student by the instructor and sympathy with the problems which confront him will do much to establish him on a firm basis in the group. Personality clashes at this level are not inevitable; they may be resolved or avoided by intelligent interpretation by the instructor of the needs of the student. The majority of all learning takes place in a group situation through interaction of the group, and the student who is at odds with the group or who cannot get along with the instructor is at a serious disadvantage.

Most training is best administered through the company organization, with senior petty officers of the company carrying out the training programs under the company commanders. The training should be consistent with the following guidelines:

1. It must be closely integrated and coordinated with the daily operations of the battalion. The plan and organization for training must not interfere with the essential construction functions.

2. Concentration on the construction schedule should not be so extreme that opportunities for training are overlooked; some types of training may even have an immediate beneficial effect on the progress of the job.

3. Maximum advantage should be taken of the opportunities to derive training benefits from routine operations.

Motivation

Motivation may be defined as the effect of a group of incentives, physical, psychological, or social, which persuade an individual to a certain behavior. In the Naval situation, it may be

assumed that physical needs are cared for. The social and psychological drives, therefore, are the ones with which the training program must be most concerned.

The most efficient learning takes place when the student has a strong desire to achieve an actual and significant goal. His reasons for this desire may be many and varied. Future security, recognition, monetary renumeration, social or professional distinction are all factors which may motivate an individual to attain a goal.

CATEGORIES OF TRAINING

Categories into which training is classified, at least for the purposes of this chapter, are ON-THE-JOB training and FORMAL training. These categories, together with hints for conducting such training, will be discussed briefly in the remaining pages of this chapter.

ON-THE-JOB TRAINING

On-the-job training is mainly for the men who already have skills and are on the job. It is usually controlled through daily job assignments.

In general, the objectives of on-the-job training in the Navy are: to broaden a man's work experience, to improve his work methods and increase his production, and to provide training for him in the application of basic skills to specific work assignments. For example, future work plans require installation of pole lines where the transformer bank is connected. The lines are "hot." Maybe you have just joined the battalion and you are not sure of the capabilities of your men, or perhaps you believe that some men need additional training in the use of "hot sticks."

The following on-the-job approach is simple. The next time service can be interrupted on a line that needs repairing (or installing) a good idea is to deenergize it, and then assume, for the purposes of training, that the line is hot. Direct the men to install the pole and make the connections under hot line conditions. This makes it possible to make a check on a man's skills as well as his understanding and proper observance of safety precautions.

Other jobs can be undertaken on the job primarily for their training value. For example, the proper bending of conduits into 90° elbows, offsets and saddles requires a lot of practice. This can be accomplished with scrap leftover pieces of conduit during occasional slack periods, when advance work, preparatory work, and fill-in work can be scheduled. This is not busy work, nor is it wasted effort. As a matter of fact, it will probably result in the saving of many feet of conduit that may otherwise have been improperly bent.

As a usual thing, since on-the-job training is in the production environment, it will be your job as a CEC, to be directly concerned with supervision. You will undoubtedly observe subject matter areas where a man requires additional instruction but where the area of instruction is not of a type that can be conducted on the job. Reading blueprints or making mathematical calculations are examples. In such cases, formal training situations will have to be planned. Planning for this type of training should be coordinated, however, by the battalion training officer.

FORMAL TRAINING

Training requirements which grow out of a job, but which cannot be taught on the job, may require a formal, group instructional setting. It generally takes place during regularly scheduled training periods during the work day, and it may or may not be voluntary on the part of the trainees participating. Such training usually is in a group or classroom instructional setting.

Broken down as to subject matter, formal training may be arbitrarily divided into two areas:

1. Subject matter required for advancement in rating. Here the instructing petty officer conducts training in general subject matter areas such as mathematics, blueprint reading, or basic electricity. In this training situation men from other Construction Ratings will also likely participate, since knowledge in mathematics, for example, is a requirement for several ratings. At other times, in connection with advancement in rating, cross training is required. Here the CEC instructs men from service ratings in subjects required for the general rating. And still at other times, he may lecture and demonstrate to CE strikers on subjects such as electrical theory, power distribution, or telephone cable splicing, telephone switchboards, electric motors or generators, wiring or any other related subject.

2. Subject matter required for the solution of an immediate problem which may or may not have a bearing on rate training. The predeployment training of the detachment that participated in Deepfreeze Operation II is an example. Group training where work simplification is necessary to make work schedules mesh—as when Builders, Steelworkers and Construction Electricians working on a common job run into "dead time" because one of the groups, or perhaps all three, are using cumbersome work techniques—is another.

HINTS ON CONDUCTING TRAINING

Restudy the training chapters in Military Requirements for Petty Officers 3 & 2, NavPers 10056-A and Military Requirements for Petty Officers 1 & C, NavPers 10057-A for guidelines for conducting training.

CLASSIFICATION OF SUBJECT MATTER

The Navy classifies its subject matter into three types: KNOWLEDGE, SKILL, and ATTITUDE. How you organize and conduct training depends upon what you want or must teach. There is no "best" method. Training on-the-job is different from training in a formal, classroom situation, although there are some common techniques,

Knowledge Type

Knowledge-type subject matter is that which is taught to build up a store of useful facts, principles, theories, and so on. This type of subject matter is usually presented in a formal training situation. Instruction in a-c and d-c theory, for example, is knowledge-type subject matter. Common properties of electrical circuits is knowledge-type subject matter. Instruction in these, and other such subjects, would probably not begin on the job. After theory and principles are developed, however, their application might well be demonstrated either under formal conditions or in an on-the-job training situation.

Self-study by men of the Navy Training Course, Construction Electrician 3 & 2, NavPers 10636-E, is an example of men acquiring knowledge-type subject matter. The correspondence course available to them carries questions to determine how well they have gained information.

Skill-Type

A skill-type subject—mental or physical—is subject matter taught to help a man acquire an ability to perform required jobs with ease, speed, and precision. The teaching approach to this situation would, of necessity, be quite different from a knowledge-type instructional situation. Skill-type instruction usually is the next step in instruction following the presentation of knowledge-type instruction; or it may be instruction born of necessity on the job. And, additionally, it may be skill training planned by a CEC to see if a striker who has read a chapter in Construction Electrician 3 & 2, NavPers 10636-E, on telephone cable splicing can actually splice a cable.

If need for instruction in a skill-type subject grows out of a job, it may be taught on the job, or it may require instruction, at least for introductory information, under formal conditions. Later, for application and practice, an on-the-job training situation may be appropriate. Teaching the use of "hot sticks" (referred to later) is an example. In another example, a CEC might, in the absence of a CET striker, teach a CEW the on the job skills necessary to make minor repairs to telephone wiring, subsets, and signal circuits.

Attitude Type

Attitude-type subject matter is selected and taught to create proper feelings, understandings, respect, and the like. Safety precautions could be attitude-type; so could military courtesy. Both might be knowledge-type, too. "Seabee Accomplishments" is an attitude-type subject. Attitude-type subject matter can be organized in the same manner as knowledge-type subject matter.

CARRYING OUT AN INSTRUCTIONAL PROGRAM

The two categories of training (on-the-job training and formal training) have been introduced, and the three types of subject matter have been described. Now for some practical ideas of carrying out an instructional program. Two situations are assumed. In one it is proposed to use, purely as a point of departure, the qualification for advancement in rating which requires you to instruct in a-c and d-c theory. The other is training to solve, for example, the

problem referred to earlier where it was observed men did not have sufficient skill to use "hot sticks" in working hot lines.

The presentation and suggestions about to follow are included to give you ideas of how you might fulfill your teaching responsibilities. The hints given are not to be construed as standards one is bound to observe.

Under the first assumed training situation—to fully satisfy your observers that you can instruct in application of a-c and d-c theory—may take from 8 to 10 hours of instruction time, plus a considerable amount of planning time, probably 2 to 3 times the amount of instruction time, before the instruction starts. Under the second assumed training situation of using "hot sticks," the time required will depend upon the receptiveness of the trainee to learn and upon the frequency of the opportunity for training.

During the planning stage of any training, the following actions on your part are necessary:

1. Ascertain what the training requirements are.
2. Prepare an outline of instruction.
3. Determine the training aids, materials, and equipment that you will use.
4. Prepare lesson plans, lecture notes, and instruction sheets to complement the instruction.

Outlining the Instruction

Having learned what the training requirements are, perhaps the first bit of planning is in connection with the preparation of a complete outline of the scope of the instruction. One method of preparing such an outline is to make a quick survey of the subject matter field. Review the Navy Training Courses bearing on the subject. After this survey, broad areas of instruction will begin to shape up in your mind. For example, to teach the practical application of a-c and d-c theory, some CECs have demonstrated their ability to teach by using the following areas of instruction:

1. Simple electric circuits
2. D-C series and parallel circuits
3. D-C compound and bridge circuits
4. A-C circuit theory

A simple outline for the teaching of "hot sticks" might look like this:

1. Need for use of hot sticks
2. Brief history of hot sticks
3. Description
4. Demonstration of use of hot sticks
5. Practical application

Within each of the broad areas identified for training, the next step is to develop topical outlines, and arrange them in a systematic manner, so that each topic and subtopic within the outline rests securely upon information developed in a preceding topic. For example, in the first assumed training situation, you may have arbitrarily decided that one topic within the broad topic of "D-C Series and Parallel Circuits" might be "Direct Current Circuits." Another might be "Ohm's Law." A partial outline of instruction might appear as follows:

1. Direct current series circuits
   a. Series circuit connections
   b. Resistances in series
   c. Current flow in series circuits
   d. Voltage in series circuits
   e. Demonstration of series circuits
      (1) Series circuit resistance
      (2) Series circuit current
      (3) Series circuit voltage
      (4) Open circuits
      (5) Short circuits
2. Ohm's Law
   a. Ohm's law in simple circuits
   b. Ohm's law in series circuits
   c. Ohm's law demonstrated
   d. Experiment on Ohm's law

After subject matter is selected, but while a detailed outline is being prepared, make a list of all training aids, special devices, equipment and tools which will be useful in teaching. If instruction is to take place at a time in the future which permits ordering training film, transparencies, and other training devices, include these in the list.

Before, after, or concurrently with the development of the training aids and equipment list, or even the outline of instruction for that matter, make also a list of all texts and instruction books that are to be used in preparing for and in presenting the lessons.

Based on the outline of instruction, the instructor next develops lesson plans for specific training periods.

Preparing Lesson Plans, Instruction Sheets, and Lecture Notes

LESSON PLANS.—A lesson plan is the blueprint the instructor uses to teach a specific topic or lesson. When the planning previously discussed has been accomplished, a lesson plan is not difficult to prepare. Lesson plans can be in many forms. The following main parts of a

lesson plan have been used in Navy training for a good many years: title of topic, objectives, training aids, references, introduction, presentation, application, summary, test, and assignment. A format for use in preparing a lesson plan is given in figure 10-1.

It will be observed in figure 10-1 that the instructor is cued to do certain things at certain times. Directly opposite or immediately below various points in the outline of instruction in the presentation section of the lesson, the instructor includes methods he will use to teach, questions he will ask, or problems he will work.

It is presumed that when one teaches he is thoroughly trained and already has acquired the technical information he expects to impart to the class. He may, nonetheless, in advance of his presentation, prepare his own lecture notes which will parallel, as necessary, the points in his lesson plan. Figure 10-2 shows a partial set of lecture notes on the Electron Theory which the instructor might want to prepare and refer to as he teaches.

INSTRUCTION SHEETS.—To augment the teaching and to complement the lesson plan, the resourceful instructor may enrich his teaching by using instruction sheets.

Several types of instruction sheets are used in Navy training:

1. Information sheets
2. Job sheets
3. Assignment sheets -

These sheets are instructor made and are designed to assist the trainee in the learning process. They may be planned for in the lesson plan as a part of formal instruction, or be used in a self-study situation where the time the instructor can give individual instruction is limited. Information sheets are developed when a knowledge-type subject has been introduced and the instructor desires to give the trainee information that he must know in order to do a specific job, or jobs. Information sheets may be used to introduce general or related information. Figure 10-3 shows an information sheet on D-C Series Circuits; and figure 10-4 shows an information sheet on "hot sticks".

Job sheets may be used after you have provided theory and have demonstrated how a skill-type job is to be performed. Job sheets may be used in class as an integral part of the lesson, or they may be used in a self-study situation where the instructor is available for consultation and can make frequent checks. Job sheets, as such however, are not generally used to teach a man how to do a job. Rather they provide the trainee with a directed means of applying the knowledge he has gained. As for example, job sheets may be prepared to check a man out in performing calibrations, adjustments, tuning, testing, and troubleshooting. Job sheets ought to include situations where the user makes mental decisions similar to those he will make while maintaining and/or troubleshooting his equipment. Figure 10-5 will give you an idea of the format and contents of a job sheet that might be used in training in the application of a-c and d-c theory; figure 10-6 shows a job sheet for using hot sticks.

Instruction that is of a continuing nature requires that assignments be made. Assignments, of course, can be made orally and can be of a general nature, but more discipline and direction can be put into the learning process when frequent use is made of prepared assignment sheets. Assignment sheets are particularly helpful in self-study situations. For example, figure 10-7 might well have been prepared for use for a home study assignment, after the instructor had introduced Ohm's law and had solved several problems.

Conducting Cross Training

Cross-training—that is, preparing men in service ratings for advancement to the general rating—is an important part of your training job. Before any of the CE2s (CEP, CES, CET, or CEW) can be advanced to CE1 they must all be familiar with the duties of the other service ratings.

One preliminary step you can take toward fulfillment of your responsibility in cross-training is to make a careful study of the qualifications for advancement in rating found in appendix of this text. Rule off a piece of paper into columns headed as follows:

Common quals	CEW	CEP	CET	CES

Study the quals, and list those in which all service rates must be checked out, and list them in the first column. Obviously, quals in the first column represent knowledge and practical factors the men have already been checked out in, and except for refresher training, you

SUGGESTED LESSON PLAN FORMAT

I. TOPIC ______________________________ QUAL. NUMBER __________

II. OBJECTIVES (of the lesson) Should be written as LEARNING OBJECTIVES. (i.e. the minimum basic behavior pattern to be achieved by every member of the class. The objective should state the condition under which the behavior is to be obtained and to the standard (% of accuracy of proficiency) the performance must meet.

III. MATERIALS

List references, training films, other training aids, shops, and equipment to be used in preparing and presenting the lesson.

IV. INTRODUCTION

List points that will arouse trainees' interest and make them want to learn. Include what you expect trainees to accomplish during the training period, why the lesson is important, how, when, and where the trainees will apply it.

V. PRESENTATION

Make a complete outline of all parts of the lesson in the order in which you will present them. Include material from any pertinent job or subject matter analysis.

Indicate directly opposite or immediately below the various statements in your outline the methods you will use to teach them. For example, some of your typical notes will be: Ask the following questions; draw this diagram on the blackboard; demonstrate how to use this too; use chart No.____ to illustrate this principle, etc.

List questions on key points to be asked in order to stimulate trainee thinking and to determine trainee understanding and learning.

VI. APPLICATION (by the trainee)

Indicate in your outline the activities that you will have the trainees actually do during the lesson to apply it. Typical notes could include: Have all trainees solve the following problem; select a trainee to assist in demonstrating this operation; have all trainees perform training in the practical factors where required.

VII. SUMMARY

Recapitulate main points to strengthen the instruction.

VIII. TEST

Describe here the means for determining the effectiveness of your instruction. A fairly reliable estimate of trainee understanding and achievement can be obtained by judicious oral questioning and by close observation throughout the lesson. Short oral, written or performance tests provide an additional check on trainee learning.

IX. ASSIGNMENT

For maximum learning, it is desirable to give trainees a work assignment for the next lesson. Be sure to include what, how, when, and why for every assignment that you make.

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Figure 10-1.—Suggested lesson plan format.

LECTURE NOTES

A. Electron theory

1. Molecule

Is the smallest possible particle a substance may be broken down into and still retain its physical identity. Molecules can be further broken down into atoms.

C. Current electricity

Current electricity is electrons in motion. If we cause electrons to flow from one point to another, an electric current exists between these two points. In order that current may flow we have a conductor.

1. Direct current

Is a steady flow of electrons through a conductor in one direction ONLY.

a. Sources

(1) Batteries

(2) Direct current generators

(3) Rectifiers

2. Alternating current

A conductor carrying alternating current electricity has electrons passing through it in one direction for a very short period of time, then the direction of electron flow is reversed, and the electrons flow through the conductor in the opposite direction for the same

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Figure 10-2.—Lecture notes that may be used to complement the lesson plan.

INFORMATION SHEET

D-C SERIES CIRCUITS

INTRODUCTION

D-c series circuits, the simplest type of electrical circuit you will encounter, must be learned first.

A thorough knowledge of d-c series circuits will aid in understanding current flow and polarity of voltage drops and voltage divider networks in future circuits.

REFERENCES

a. NavPers 92022, Basic Electricity, vol. 2
b. NavPers 10086A, Basic Electricity

INFORMATION

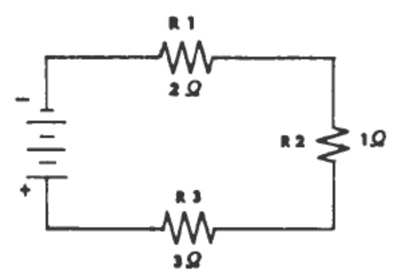
A series circuit is so designed that the current has only one path from the negative side of the source to the positive side. The current at any point in the circuit is the same as at any other point at a given time. This is true because there is one path only for the electrons to follow, and the same number of electrons that leave the negative terminal must be returned to the positive terminal, regardless of what the source may be (battery, generator, power line - - -).

The total resistance in a series d-c circuit is the sum of all the resistances, and the current is the same through any of the resistances.

The voltage will divide throughout the circuit proportionately with the size of the resistance. This can be proven by using Ohm's Law, E = IR, with E = voltage, I = current and R = resistance. The source voltage must be consumed or dropped in the circuit. Voltage drops have polarity identical to source voltage.

The polarity of a voltage drop can easily be determined. The end of the resistance closest the negative terminal will have negative polarity with respect to the positive terminal, and the end nearest the positive terminal will be positive with respect to the negative terminal. This is true because electrons flow from negative to positive, and in order to have current flow, a difference of potential must exist.

Let us take a simple circuit and see how the voltage divides.



First find total current. Ohm's Law says $I = \frac{E}{R}$. This being a series circuit we know that
Rt - R1 + R2 + R3
Rt = 2Ω + 1Ω + 3Ω
Rt = 6Ω.

We also know the current is the same throughout the circuit. Therefore, we can easily find I, using Ohm's Law $I = \frac{6V}{6\Omega}$

I = 1 amp.

26.134.1

Figure 10-3.—Information sheet: D-C Series Circuits.

The voltage drops are proportional to the size of the resistances. Now apply Ohm's Law and see how the voltage is dropped. First, find the voltage dropped by R1.

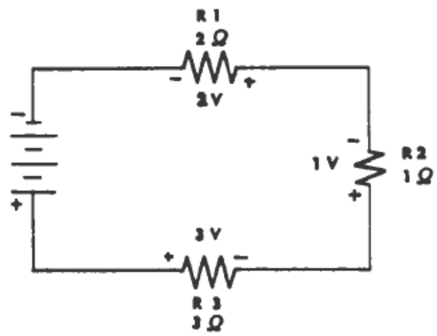
$E1 = I \times R1$	R2	$E2 = I \times R2$	and R3	$E3 = I \times R3$
$E1 = 1a \times 2\Omega$		$E2 = 1a \times 1\Omega$		$E3 = 1a \times 3\Omega$
$E1 = 2V$		$E2 = 1V$		$E3 = 3V$,

thus, Et $\quad Et = E1 + E2 + E3$

$Et = 2 + 1 + 3$

$Et = 6V.$

To determine the polarity of the voltage drops, use the rule stated earlier. The end of the resistance nearest the negative terminal is negative with respect to the positive terminal, and the end nearest the positive terminal is positive with respect to the negative terminal. Thus,



Another thing to be considered in a d-c series circuit is power dissipation. When there is current flow power is used. The Ohm's Law formula for finding power, $P = I \times E$ where P = power in watts, I = current in amps and E = voltage. Thus, a circuit with 1 amp of current and 6 volts will consume 6 watts of power, $P = 1 \times E$

$P = 1 \times 6$

$P = 6W.$

Other forms of Ohm's Law for power are $P = I^2R$ and $P = \frac{E^2}{R}.$

Remember, that to have current flow there must be a complete path from the negative terminal to the positive terminal. If a lead breaks or a resistor burns out, no complete path is available, and therefore no current flows. The circuit becomes inoperative until repairs are made that will restore the path for current to flow.

When there is more than one path, current always seeks the one of least resistance. If there exists a path from the negative to the positive terminals that would bypass the resistors the current would use this path. This action would cause "a short circuit," making the circuit inoperative. Steps must then be taken to remove this path to restore proper operation.

One more thing to be considered is Kirchoff's Law of voltages, which states that the algebraic sum of all the voltages in any complete electrical circuit is equal to zero. In other words, the sum of all positive voltages must be equal to the sum of all negative voltages. For a thorough explanation of Kirchoff's Law of voltages, read page 58, and column 1 of page 59 of NavPers 10086-A.

26.134.2

Figure 10-3.—Information sheet: D-C Series Circuits—continued

INFORMATION SHEET

HOT STICKS

INTRODUCTION

As the use of electricity increases, the need for maintaining continuous service also increases. Rather than interrupting power service so that crews can work on cold lines, maintenance crews must learn to use hot line tools, called "hot sticks."

Men working on high voltage lines with hot sticks must be constantly aware of the danger involved, and consequently should use more caution than when working on low voltage or cold lines.

REFERENCES

a. Construction Electrician 3 and 2, NavPers 10636-D

BRIEF HISTORY

Hot line tools were first intended for work on lines up to 34 KV, but many linemen were hesitant to perform hot stick operations on what was then considered such a high voltage. Because of this fear, most of the men were unwilling to work with these tools on voltage above 22 KV.

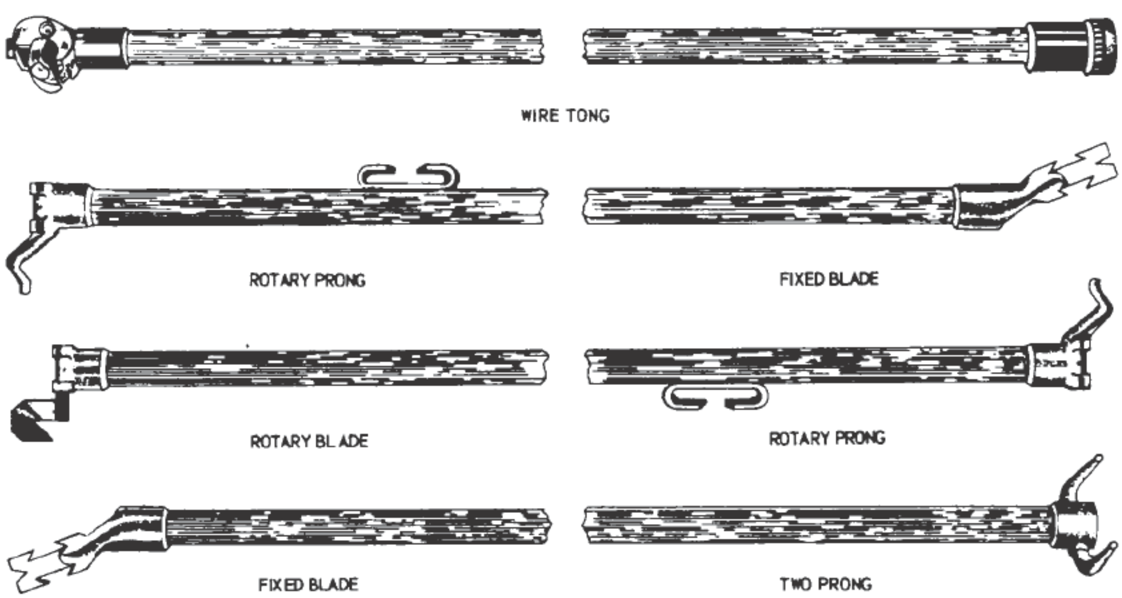
As linemen began to realize that the hot sticks kept them at a safe distance from energized lines, they began to lose their fear.

In recent years hot line tools have been developed that will successfully handle hot lines having more than 345 KV (345,000 volts). Today there are very few jobs that cannot be performed hot.

The sticks shown as a part of this information sheet are commonly used. Hot line tools range from 3 feet to 12 feet in length.

Many hot sticks are made of wood. Sitka spruce, maple and oak have been found to have the most desirable characteristics. To prevent warping, the insulated sticks are laminated in two, three, or four sections, depending on the pole diameter. In recent years hot sticks are being made of plastic and fiber glass. These materials have a high moisture-absorption resistance, are more rigid than wood, and are highly resistant to abrasion and common solvents.

All hot sticks regardless of diameter have insulating qualities capable of withstanding 75,000 volts, 60 cycles, across each foot of pole length for a period of 5 minutes.



26.135

Figure 10-4.—Information sheet: Hot Sticks.

JOB SHEET

TITLE: SERIES GENERATORS

INTRODUCTION: The purpose of this job is to familiarize the trainee with the connections and internal characteristics of the series generator. Many naval installations use compound generators, and knowledge of series generators will help electricians better understand the operation of compound generators.

EQUIPMENT:
1. Compound machine
2. Lamp bank
3. Four cone resistors
4. Multimeter with leads
5. 0-20 d-c ammeter
6. Two fuses and fuse pullers
7. Voltage tester
8. (2) ½ x ½ - 20 bolts with nuts

PROCEDURE:
1. Draw a diagram of a series generator, use correct terminal markings.
2. Check generator by hand, rotate armature, check for tight coupling.
3. Connect voltmeter to armature leads.
4. Rotate prime mover by hand and observe voltmeter deflection. Mark negative lead, "A1", positive lead "A2".
5. Connect generator as per diagram.

   NOTE: IF IN DOUBT AS TO CONNECTIONS, ASK INSTRUCTOR.
6. Install fuses in prime mover circuit, test fuses.
7. Start prime mover with VOLTMETER ON HIGH SCALE.
8. Check voltage
   a. Close load switches.

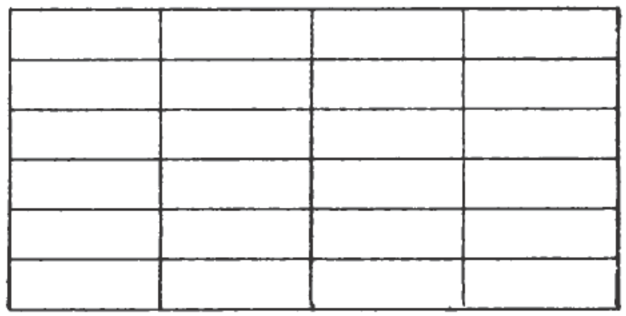
26.136.1

Figure 10-5.—Job Sheet: Series Generators.

1. If voltage fails to build up, adjust neutral plane.
2. If voltage still fails to build up, reverse series-field connections.

9. Close load switches one at a time and plot voltage curve.

10. Open load switches. Record no-load voltage on graph.



11. Secure machine, tag and pull fuses.

12. Disconnect all connections, but leave equipment at your station.

QUESTIONS:

1. ________________ is necessary to produce the small voltage deflection at no load.

2. The voltage ______________ as the current increases.

3. How do series-field coils differ from shunt-field coils?

REFERENCE: NavPers 10546, Electrician's Mate 3 & 2.

26.136.2

Figure 10-5.—Job Sheet: Series Generators—continued

JOB SHEET

USING HOT STICKS

INTRODUCTION

In your job as Construction Electrician it will often be necessary to work on lines where service cannot be interrupted. For example, if you are installing pole lines where the transformer bank is connected, you must learn to use "hot sticks." The purpose of this job sheet is to provide information that will assist you in learning to install a double "hot" tie on a single insulator. See the illustrations which are a part of this job sheet.

EQUIPMENT

1. The following hot sticks: fixed blade, two prong, rotary prong, and rotary prong

2. Simulated poles mounted with insulators

3. Tie wire

4. Lineman pliers

PROCEDURES

1. Make a 1-inch loop on the end of the tie wire and determine the length required for a minimum of six turns around the conductor. Then add the circumference of the insulator plus the additional length required for at least two turns at the middle of the double tie to secure it to the insulator. Add sufficient length and form a loop on the opposite end of the tie wire.

NOTE: On both double and single ties, tie wires should be attached to the insulator with a clockwise twist. The ties should also be wrapped around the conductor in a clockwise direction on each side of the insulator to prevent untwisting the tie wire where it is attached to the insulator.

2. Make up the other wire of the double tie the same length and place both tie wires around the insulator so that the looped ends are in opposite directions and parallel with the insulator groove.

3. Form the double ties closely around the insulator and secure them to the insulator with at least two turns made with lineman's pliers. After wrapping, each double tie should be tight around the insulator and still be in alignment with the insulator groove.

4. Shape the tie wires to form a letter "S" to prevent their extending too far from the insulator.

5. Secure the conductor in the insulator groove and hold it in place by applying downward pressure on the wire tong at the opposite side of the insulator where the first tie is to be made.

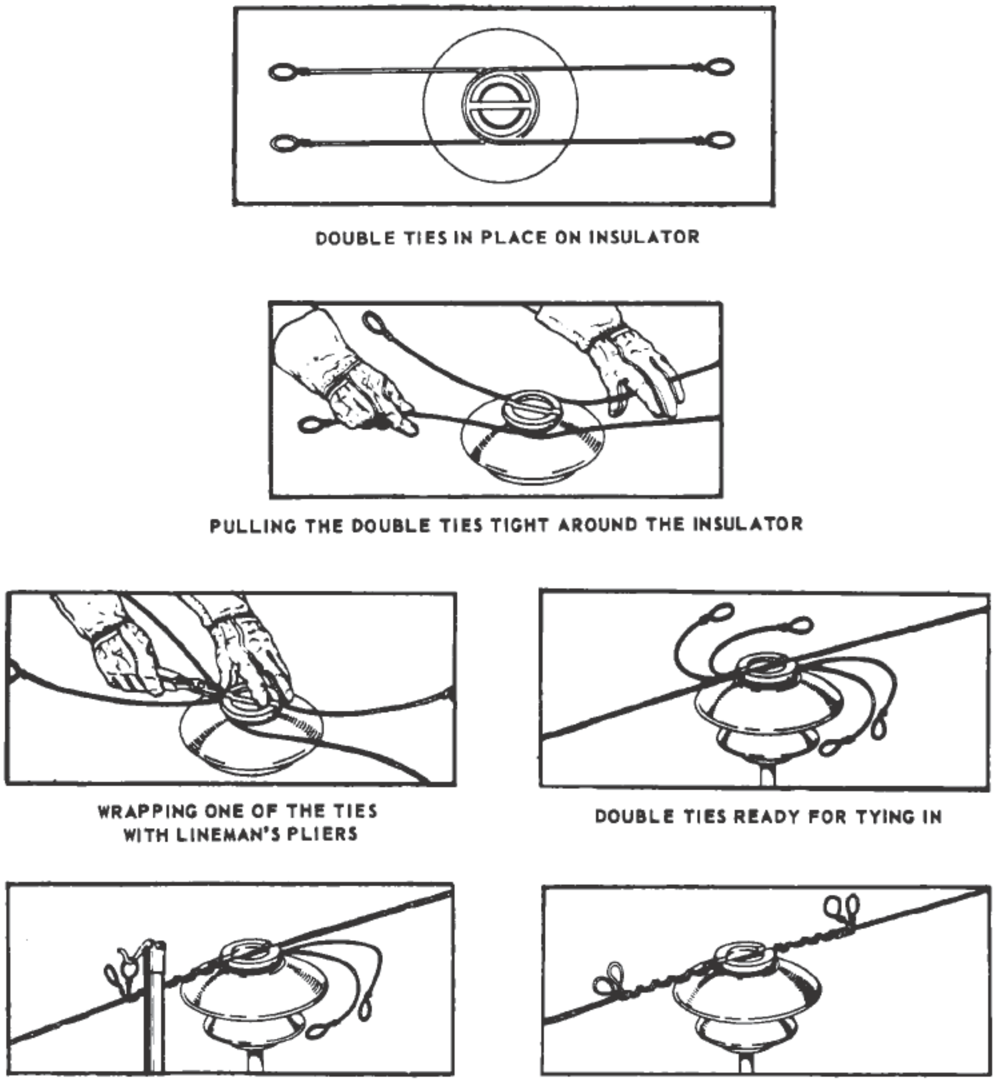
6. Using a ROTARY PRONG or other appropriate tie stick (see illustrations), rotate the two wires of the double tie progressively along the wire to produce a smooth, even tie. The ties should not overlap each other on the conductor.

7. After tying the conductor at one side of the insulator, tie the opposite side in the same manner. When the tie is completed, only the loops should extend out above the conductor.

26.137.1

Figure 10-6.—Job Sheet: Using Hot Sticks.

will not be concerned with them. The remaining columns, however, you will be concerned with. As you find quals applicable to each of the service ratings, make an entry in the appropriate column. These columns become a guide to the subject matter for which you will be responsible in cross-training. If the man you are to train is a CEW moving up to the general rating,



DOUBLE TIES IN PLACE ON INSULATOR

PULLING THE DOUBLE TIES TIGHT AROUND THE INSULATOR

WRAPPING ONE OF THE TIES WITH LINEMAN'S PLIERS

DOUBLE TIES READY FOR TYING IN

TYING IN ONE SIDE OF INSULATOR WITH A ROTARY PRONG

BOTH SIDES OF THE DOUBLE TIE TIED IN

26.137.2

Figure 10-6.—Job Sheet: Using Hot Sticks—continued

concentrate on the subject matter carried in the CEP, CET, and CES columns. In other words you are responsible for training in the areas and for the quals in which the man has not previously checked out.

After the chart has been made, inspect it in terms of subject matter for possible organization for training. Some of the material can be learned by study of the appropriate Navy Training Courses. Other subjects can only be learned by practical experience. Whenever possible, use an on-the-job training situation, but even here, as has already been pointed out, some formal training away from the job will probably be necessary. It is not likely, for example, you could teach a man the principles and theory of a-c and d-c motors by immediately assigning him to a job where he had to operate and service advanced-base-type generating equipment. Principles and theory are knowledge-type subjects and would have to be introduced under more formal conditions.

Cross-training is a term and there are no techniques of teaching which are peculiar to it.

It must all be planned in advance, following the suggestions appearing earlier in the chapter.

TRAINING EVALUATION

The final phase of any training program has to do with the evaluation of progress in terms of the original objectives. Is the training program really doing what it was designed to do?

Evaluation may be either formal or informal in nature. Formal evaluation is carried out through a testing program to find out what knowledge the student has gained, or what level he has reached. Informal evaluation consists mainly of supervision and contact on a more personal plane; interviews, conferences, and inspections are used to determine whether teaching procedures and environment are conducive to the learning process. The supervisor

ASSIGNMENT SHEET

Problems on Ohm's Law

INTRODUCTION

Ohm's Law for power calculations may be applied to a great many everyday problems wherever electricity is at work.

Consider one of the most common examples--that of the incandescent electric light. Incandescent lamps for use in constant-potential circuits in homes and factories are rated in volts and watts. How much current do they take? How much resistance do they possess? If high powered, they may draw several amperes; if low in wattage rating, they may take only a small fraction of an ampere.

PROBLEMS

Using the Ohm's Law formulas, solve the following problems:

1. What is the current rating of a 100-watt 120-volt lamp?

2. Use the answer to the first problem and find the resistance of this lamp.

3. How much does it cost to use this lamp 4 hours each evening for 30 days at 3.2 cents per kilowatt-hour?

4. How much would it cost to operate a window air-conditioner rated at 120 volts and 9.4 amperes in use 10 hours a day for 30 days?

26.138

Figure 10-7.—Assignment sheet: Problems on Ohm's Law.

must be able to recognize defects when he sees them, and he should know how to apply corrective measures and to motivate his instructors to the solution he proposes.

Navy schools do not differ from civilian institutions in the need for effective evaluation of teaching and teachers. Remedial and motivational supervision by the Navy administrator can certainly be expected to result in a better quality of instruction.

Formal Evaluation

Test construction and administration are highly technical processes used to discover or measure the present knowledge or achievement factor of the student, or to reveal weaknesses in order that they may be remedied. The most effective and realistic purpose of a testing program is to aid the student. In a test situation, not only is the student being measured but also the teacher's ability as an instructor. Consistently poor results from tests may indicate faults of the school that are completely beyond the control of the student.

Three types of tests that find wide use in the Navy are aptitude tests, diagnostic tests, and achievement tests.

Aptitude tests have a valid use in the Navy. At the time of recruit training such tests are administered to all new enlistees and the results are used as a basis for selection of candidates for the various service schools. Aptitude test scores are used as indications that certain qualities and abilities may be present in certain people. Correctly used, these scores can be of great aid in assigning men to the different occupational ratings. Each man's score is entered in his service record which accompanies him to his several duty stations and is available to any of his superiors.

Diagnostic tests should be used at the beginning of the training course to discover what each student knows before instruction begins. They should be used as an index of individual differences. In a good training program, these differences are taken into consideration, and the instructor knows something about each of his men at the start of a course. Thus the diagnostic test can be an invaluable teaching aid. The test itself must be as thorough as it is possible to make it, if the diagnosis is to be at all accurate. In this manner weaknesses are revealed and areas for more complete study are suggested.

Achievement tests are designed to measure attainment or progress and need not be as comprehensive as diagnostic tests. The achievement test is a sampling of knowledge or ability, rather than an all-inclusive examination.

Many forms and types of achievement tests are available for use but certain tests adapt more readily to specific teaching techniques. Two main divisions of tests are the nonwritten, or performance type test, and the written examinations of various sorts. Performance type tests are better for testing shop or laboratory skills, while written tests lend themselves better to the testing of knowledge and attitudes. This is by no means a hard and fast rule; shop trainees can easily be given written tests, and mathematics or accounting students can be tested on their ability to perform experiments and problems. Individual situations will help to determine which particular approach to the testing question should be taken.

Performance Tests

The performance type test, which is usually used to measure manipulative and mechanical skills as well as knowledge, may be given in many ways and under different conditions. For this reason it is adaptable to shop or vocational training. However, the purpose of the test and the amount of knowledge it is planned to measure should be firmly fixed in the mind of the instructor. A common failing among instructors seems to be the notion that a performance test can be given at any time, with little or no preparation. This most certainly is not the case. The performance test is a valuable instrument, but its administration must be well thought out and thorough. It is absolutely imperative that this test be given to all groups in the same way, and that every student be marked on the same basis.

Written Tests

The planning and administration of the written test requires as much effort and care as the performance test, but there is a wider variety of written tests from which to choose. Here again, the knowledge to be tested will indicate fairly well the type of test to be used. The instructor will find it to his advantage to vary the kind of test given, for it is entirely possible for a group of students to become "test wise" if they experience one type of test too often.

The multiple-choice test is a good type and readily adaptable to almost any subject matter. It may be used effectively to present problems involving reasoning based on knowledge and can easily be constructed so as to limit guessing to the barest minimum. There should be at least four choices and not more than six.

The matching test has its uses, but is not as satisfactory as the multiple-choice test, which it resembles to some extent. The directions for each item must be stated clearly. There should be more suggested choices than elements to be matched. This test is best used with technical material such as parts of a machine or steps in a process. If poorly constructed, many questions can be answered on a common-sense basis by the process of elimination; this is easier to do than the instructor may suppose.

The true-false test is unusually popular because of its supposed ease of construction and administration. If its popularity rests solely on these factors, such popularity is undeserved because, actually, it is extremely difficult to make up a good true-false test. Because the test encourages guessing it is perfectly possible for a weak student to make a score out of all proportion to what he knows. The wording of true-false statements can be very perplexing; words like "hardly," "usually," "sometimes," "all," "never," should be used with caution. They are either confusing, or they give an indication of the correct answer.

The relatively inexperienced Navy instructor should not try to construct true-false tests until he has been on the job for some time. There are other good tests that will serve the purpose just as well, and which will not subject the unwary instructor to the pitfalls and shortcomings inherent in the true-false test.

The completion item test is one of wide application, and when used in the proper fashion, it can be one of the most valuable instruments in the testing field. As with other tests, it must be constructed with care. The instructor must be sure there is one, and only one, correct answer or he will find himself in trouble with his students. With a little practice in test construction, the average Navy instructor should soon be able to make up a good completion test. There are fewer dangers to be avoided in this type of test than in most others.

The essay type examination is one used more frequently in subjective courses taught in the traditional or formal manner, and its use in shop or vocational training is not recommended. It is difficult for a Navy instructor to make up a good essay test, and even more difficult to correct and grade such examinations. It takes longer for students to answer essay type questions than it does completion and multiple choice questions, and consequently not so many points can be examined or tested in the same time. The essay test invites bluffing, and the student who is facile with words may well score higher than a student who is really better grounded in the material but less fluent.

Written tests which include up to three different types of the above tests may be planned, but the use of more than three types tends to confuse the students. The use of NavPers 91961, A Manual for Use in the Preparation and Administration of Practical Performance Tests, and NavPers 16808-A, Construction and Using Achievement Tests, and chapter 10 of NavPers 16103-C, Manual for Navy Instructors, can be very helpful in constructing good tests.

Informal Evaluation

Qualitative evaluation is one of the primary duties of the school supervisor or of the administrator of the training program. In general, supervision for evaluative purposes should function through the teaching staff. The supervisor's main job is to work with people, even though he also has to deal with such things and projects as buildings, grounds, supplies, assignments, and time schedules. Ideally, good supervision improves the attitudes and abilities of instructors at the same time that it makes for good working conditions.

Because it is concerned mainly with people, good supervision revolves around the appreciation of individual differences, both in instructors and in students. It is based on respect for human personality. It is the duty of the supervisor to afford his people the opportunity for improvement by understanding their problems and advising as to their solutions. This modern approach to supervision is increasingly prevalent in the Navy of today. The modern Petty Officer is better equipped psychologically for his dealings with people. The fact that the Navy is a line organization does not preclude the recognition of individual differences; it does, however, disallow a too-rugged individualism, an altogether different thing.

To be successful, supervision must emphasize that all persons concerned with a school or training organization are working toward a common goal. There can be no duality of objective between the supervisor, on the one hand, and his faculty and students on the other. A two-way flow of information and ideas is imperative if the caliber of instruction is to be improved.

Supervision in the Navy labors under a handicap not found in civilian education; the periodic transfer of both officer and enlisted personnel makes it difficult to promote a long-term attitude of teamwork. Supervision of individual instructors is restricted for the same reason. Once more, individual differences will play the major part in the interaction between supervisor and instructor, and between instructor and student. All hands engaged in training should be given information about the principles of various aspects of training and its attendant problems.

Evaluation by Follow-up

Another method of evaluation is the follow-up, the purpose of which is to check on the effectiveness of the training by contacting persons for whom the trainee works after graduation. A rating scale may be devised and forwarded to be filled out by the new superior, and in this way some perspective may be formed of the training program. This system has the weakness of all rating systems; namely, that no two people mark on the same basis. A further weakness of its use in the Navy is that it may be difficult to trace the man. Nevertheless, in some cases, a systematic follow-up may very well prove worth the effort involved.

CHAPTER 11

FOREMANSHIP

As a Construction Electrician First or Chief, you will have many responsibilites added to those which you have had at the second class level. The higher your pay grade, the more likely it will be that your main duties will consist of supervising rather than doing. You must see that work is properly planned, that it is carried out in the proper way, that the proper records and reports are kept, and that safety precautions are observed. These duties and responsibilities are a phase of foremanship; another phase, training, is discussed in chapter 10 of this course.

Foremanship duties and responsibilities are of a continuing nature. Whether you are assigned to an MCB, a detachment, an amphibious construction battalion, or a public works department, you will need to supervise men, delegate authority, coordinate operations, and train personnel. The type of activity to which you are assigned will determine just how you carry out your foremanship responsibilities. For the most part, the discussion in this chapter applies to MCB deployed to an overseas base. The general principles, however, apply to other units also.

JOB PLANNING

To get an assigned job done in the proper manner and on time requires careful planning. You will need to know exactly what is to be accomplished, when it must be completed, the number of men available to do the job, and the amount of material required. In addition you will need to coordinate your work with men in other ratings. If, for example, the plans for a job call for placing conduit through the footings or within a slab deck, you must have your crew ready to place the conduit as soon as the Builders have completed the forms. The necessary information may be provided in the form of standard drawings developed by the Bureau of Yards and Docks. In other cases, drawings may be provided by the local public works department or developed by the battalion operations office. In any event, you must study all available information carefully to be certain that you understand all important aspects of the job to be done.

HINTS ON PLANNING

As the petty officer in charge, you are responsible for the time of your men as well as for your own time. You must plan so that they will be kept busy doing constructive work. This will be to your convenience, but it should be pointed out that keeping the men in the shop each morning doing nothing while you plan is a waste of manpower. At the close of each day, you should confirm planning for the next work day:

1. Manpower. Who is to do what? How is it to be done? When is it to be finished? Knowing that idleness may breed discontent, have you arranged to have another job ready for starting as soon as the first one is finished? Is every man fully utilized?
2. Equipment. Are all necessary equipment and tools on hand to do the job? Is safety equipment on hand?
3. Supplies. Are all necessary supplies on hand to start the job? If not, who should take action?

Have a definite work schedule and inspection plan. Set up goals or quotas for the day. Have a definite plan for personally checking at intervals to see that the work is being accomplished and that the goals are going to be met. Spot-check for accuracy, workmanship, and the need for training.

Construction Electricians must be trained to do a variety of jobs by means of the rotation method, on-the-job training, or classroom work; allow time for this in your planning for a job. Time must also be allowed for handling personnel

problems, records, and military duites. A supervisor must allow time for reports and other paperwork which is necessary for the control of men and materials under his charge.

Until a petty officer learns to delegate work properly, he can never be much of a success. Everytime you find that a job has become routine, set up a simple procedure, train someone to handle the job, and from then on let that person handle it.

In delegating authority, be sure that the man concerned has the training and information necessary to carry out the work. If you find that he cannot do the job that is required, he may have to be retrained. Remember, you can delegate your authority, within reason, to subordinates; but you cannot delegate your responsibility for the final product.

Construction planning is a combination of several important considerations. In addition to day-to-day planning on the job, primary matters that must be considered in construction planning are work element estimates, material estimates, equipment estimates, manpower estimates, plant layout, material delivery and storage, work schedules, and progress control. These considerations are more or less dependent upon each other and all are taken into account in any well-planned project. The success of any project depends to a great extent upon the amount of detail and the care taken in planning it.

SCHEDULING

The various phases of a job must be carefully scheduled if it is to progress without delays. Generally speaking, the sequence of work assignments must correspond to actual construction operations. You must remember, of course, that some jobs take longer than others to complete. Thus, on a typical job, installing conduit may take considerably longer than installing underground service; you would need to use more men for the conduit than on the underground service if you needed to have these two operations completed about the same time.

It is important that every man assigned to you know his job within the framework of the schedule. In some cases, a man may not be familiar with all phases of the job to which you assign him; for instance, a man may have had no recent experience working with explosion-proof wiring. If he is assigned to that phase of an installation job, knowing this in advance would give him a chance to brush up on this type of work. Making up the schedule in advance and posting it on the bulletin board or in some other prominent place is a useful method for keeping your men informed of their forthcoming assignments.

PLANNING FOR EMERGENCIES

Part of job planning includes planning for emergencies. Certain types of emergencies, of course, are beyond your control. Unexpectedly bad weather, enemy action and complete changes in plans are examples. You can prevent many emergencies from arising, however, by planning and forethought.

Whenever possible, you should check actual details of the job against the plans. Some details, such as ground conditions for underground conduit, cannot be adequately covered on the plans. Poor ground conditions might affect the location of manholes, thus creating a problem during job operations.

In making additions or changes to structures from old plans, it is particularly important to make certain that all parts of the plans have been followed during construction. Plans which were drawn up during emergency conditions, such as during World War II and the Korean conflict, were not always closely followed. One example will demonstrate this point. At an overseas base, World War II drawings were being used as a guide for installing additional wiring in an underground distribution system. The prints called for several spare conduits in a particular manhole. When the work crew began pulling wire through one conduit, they discovered that the conduit did not extend all the way to the transformer vault, although the print showed that it did. Two lessons are apparent from this example: first, plans should be checked against the existing conditions whenever possible; and second, any change from the plans you make during construction and installation—for whatever reason—should be shown on the master set of plans. Changes on the master plans will ensure that "as-built" drawings will be available for future use.

Personnel Problems

Failure to make allowance for personnel changes can slow down work or cause a complete stoppage. Some personnel matters, of course, are beyond your control. If a man suddenly becomes ill or goes on emergency leave, you

will simply have to try to get a replacement for him or do some rescheduling. If a man is scheduled for leave or for detachment, however, and you do not take this fact into consideration when planning your schedule, the fault for any delay which results lies with you. In making up your schedule, consider military duties, special details, and similar factors that could affect work operations.

If you have a shortage of men for the job—and this is not unusual—be certain that you assign them to best advantage, according to their skills and capabilities. Never ask for more men than you can use on a job; extra men get in the way of the workers.

Materials Flow

We have already mentioned that the bill of materials should be checked during the planning stage to make certain that all materials are available or are on order. Even with this check, there is sometimes danger of running out of material. This may happen when the rate of progress on the job has been considerably greater than anticipated or when materials have been unusually slow in arriving at the job site. If either of these conditions occur, notify the officer in charge of the project. He may appoint an expediter to see that materials get to the location where they are needed. Occasionally, you or one of your men might serve as expediter; in this case, you might hand carry a requisition through the supply chain to speed up delivery. This is strictly an emergency procedure, however. Careful advance planning will normally ensure an orderly flow of materials.

Machinery and Equipment

Machinery and equipment failures may result from numerous causes, many of which can be prevented. See that your men follow proper operating and maintenance procedures. Manufacturers' instruction books and local instructions should be strictly followed. There are many examples that might be given of the misuse of equipment, but one is sufficient to illustrate the point.

Hydraulic benders are commonly used to bend 4-inch conduit. When fluid in the chamber is low, inexperienced men have been known to fill it with some fluid other than that recommended by the manufacturer—with motor oil, for instance. Improper fluids not only will not work satisfactorily, but may permanently damage the hydraulic system. Impress your men with the fact that they follow manufacturers' operation and maintenance instructions.

COORDINATION

You will need to plan ahead so that necessary equipment will be on hand to do certain work at the right time. On one particular job, for instance, there may be only one power threader, hydraulic bender, or similar item. You will need to check with other petty officers who are using this equipment to determine when such equipment will be available to do the job for which you need them.

A little coordination with other job supervisors will usually ensure that equipment is available when you need it.

A PRACTICAL EXAMPLE

To apply some of the principles so far discussed, let us set up a practical example. Assume that you are with a detachment assigned the job of constructing a four-unit building suitable as married enlisted men's quarters (MEMQ). The plans and specifications call for a rigid conduit job throughout, with electric heating, ranges, washers, and dryers as major appliances in each apartment. Let us assume also that the material and labor takeoff have been completed and that a job order number has been assigned. (See fig. 11-1.) On this job, you will have conduit in sizes from 3/4" to 4" and wire from #12 to 250 MCM or larger.

Make a list of the specific jobs that must be accomplished before the overall job is completed. Figure 11-2 gives this information in the left column, which is labeled Type of Work. To the right of this column, make several columns listing the dates on which you expect to accomplish specific jobs. Under each date column, place the number of manhours which you estimate will be required on that particular date. An X under a date indicates no work on that day. List at the bottom of the sheet the number of men and the amount and type of equipment required for the job. For this job, you will have six men available. List the names of the men and designate the lead man. Figure 11-2 shows the information which should be carried in the advance schedule.

JOB CODES

JOB ORDER NO: 29

APPROVED BY: F. R. JACKSON LCDR. OPERATIONS OFFICER

JOB: M.E.M.Q.

INSTALLATION: 14

PROJECT NO: 14261-694

TYPE WORK: ELECTRICAL

JOB CODE	
14-1	TRENCHING AND EXCAVATING FOR UNDERGROUND CONDUIT
14-2	INSTALLING CONDUIT 1½" AND LARGER
14-3	INSTALLING CONDUIT 1¼" AND SMALLER
14-4	PULLING WIRE #6 AND SMALLER
14-5	PULLING WIRE #4 AND LARGER
14-6	INSTALLING SWITCH, RECEPTACLE AND OUTLET BOXES
14-7	INSTALL SERVICE, INCLUDING PANELS AND MAIN SWITCHES
14-8	INSTALL LIGHTING FIXTURES
14-9	TELEPHONES, INCLUDING FEEDER AND TERMINALS
14-10	MISCELLANEOUS; CLEAN UP AREA, PROCURING MATERIAL
14-11	INSTALL SWITCHES, RECEPTACLES AND COVERS

26.139

Figure 11-1.—Job codes and list of jobs.

ADVANCE WORK SCHEDULE (IN M/HRS)

DATE: 4 Aug. 62

JOB: MEMQ.

SUPERVISOR: FRANKLIN CE1

TYPE WORK:	DATE / CODE NO:	AUG 7	8	9	10	11	12	13	14	15	16	17	18	19	20
INSTALLING CONDUIT 1¼"	14-3	24	24	24	24	*18	X	X	24	24	24	24	24	X	X
AND SMALLER															
INSTALLING CONDUIT	14-2	8	8	8	8	*6	X	X						X	X
1½" AND LARGER							X	X						X	X
PULLING WIRE	14-1						X	X	8	8	8	8	24	X	X
INSTALLING SWITCHES	14-6						X	X					8	X	X
AND RECEPTACLES							X	X						X	X
INSTALL MAIN SWITCH							X	X	16	16	16	16	16	X	X
AND LIGHTING PANEL	14-8						X	X						X	X
INSTALL SERVICE	14-7	16	16	16	16	*10									
(UNDERGROUND)															

*Scheduled personnel inspection.

EQUIPMENT NEEDED:

Pipe threader (Electric) to 4"
Hydraulic Bender (Pipe)

TOTAL NO. MEN: 6 (LISTED BELOW)

JOHNSON	CEW 2	FRANK	CN
BAKER	CEW 2	JONES	CN
NELSON	CEW3	FRANKLIN	CE1, LEAD MAN

26.140

Figure 11-2.—Advance work schedule.

Check to make certain that none of the men are scheduled for leave, transfer, or school.

In the early stages of this job, you may not need all six men; if this is the case, assign some of these men—perhaps two—to some other job under your supervision until the Builders get enough work on the MEMQ completed that you can use all six men.

Estimate the days on which you will need the pipe threader and the hydraulic bender, and check with the electric shop to be certain that they are available on those days.

You have now planned the job and set up a schedule. You cannot, of course, anticipate emergencies such as sickness and emergency leave. You have, however, gone as far as possible with your plans. When the work starts, you will need to make a daily time report as shown in figure 11-3. This report should account for the number of hours each man works per day on the job.

SUPERVISION

The term supervision may be defined in a number of ways. As used in this chapter, it means overseeing, directing, and inspecting the work of others.

Supervision, then, means working with people. A good supervisor knows how to get a job done by getting the most out of his men. This is the basic difference between a supervisor who is merely technically competent and one who knows how to get maximum production. It is extremely important, of course, for a supervisor to be technically competent in his specialty. Competence alone, however, will rarely get the job done when a person has to direct the work of others. As well as knowing and understanding the job to be done, a good supervisor must understand the capabilities of his men and must know the techniques of good supervision.

KNOW YOUR JOB

Your job is likely to vary with each deployment of the battalion. If the principal mission of the battalion is to construct housing, you are likely to be in charge of a crew installing interior wiring. On another assignment, the mission of a battalion may be to install portable electric power plants, including the distribution system. On some assignments, it may be necessary to install telephone systems. On most assignments, it is necessary to set up an electrical repair shop.

You may be in charge of a crew assigned to carry out any one of these jobs. To carry out the job properly, you must know exactly what is to be accomplished, deadlines for the job or portions of it, who will be your boss for the job, and the relationship with other projects. You will need to plan your part of the job with respect to materials and scheduling in the manner described earlier in this chapter. Unless you understand lines of authority, materials and equipment required, limitations of the equipment, and the capabilities of your crew, you are likely to have trouble in meeting your responsibilities.

KNOW YOUR CREW

It is not likely that you can do a good job unless you thoroughly understand the job to be done. Knowing your crew is as important as knowing the job. If a new CEW2 is assigned to your crew, you can be certain that he has been checked out in the practical factors for his rate and that he has passed the servicewide exam. Without investigation, however, you could not tell whether he is an expert in the use of test equipment or whether this is one of his weak points. Similarly, you could not tell whether he is almost ready for promotion to CE1 or whether he has just made his rate. His experience and capabilities will have a very important effect upon the type of assignment that he can handle best. Without checking, you cannot tell whether a new man is one to whom you can give very brief instructions and expect to find the job done, or whether you must keep a constant check on him. His traits may mean that you can assign him to a distant project where he can work under minimum supervision; or they may indicate that you should put him in a job where you can keep an eye on him and place a man who can work under less supervision on the distant project.

From the foregoing, it is obvious that a good supervisor needs to know the strong points and weak points of each crew member. You need to know your crew in order to make intelligent decisions about assignments, needed training, and recommendations for advancement in rating, among other things.

When you learn that a new man is being assigned to your crew, learn what you can about him; ask to see his record. Talk to

DATE: 4 AUG. 1962

NAME	RATE	JOB CODE 14-3	14-4		14-2		14-1				
JOHNSON	CEW2	4	4								8
BAKER	CEW2	4	4								8
NELSON	CEW3		3		4		1				8
FRANK	CN		3		4		1				8
JONES	CN	1					7				8
FRANKLIN	CE1	2	3		2		1				8
Total hours		11	17		10		10				48

JOB TITLE: MEM.Q. SUPERVISOR: FRANKLIN CE1

18.5.1

Figure 11-3.—Typical daily time sheet.

him when he reports; find out what he has done and likes to do. Finally, observe him closely in various work situations; you will soon learn what type of person he is.

DELEGATING

One of the most common failings of a new supervisor is failure to delegate. It is natural to want to carry out the details of a job yourself, particularly when you know that you can do the job better than any of your men. Trying to do too much, however, is one of the quickest ways to get bogged down in details and to slow down a large operation. You will often be responsible for several jobs or several parts of a job some distance apart. Obviously, you cannot be in two places at the same time. If someone is needed to make quick decisions during your absence, designate a man who is capable of making these decisions. This man should be capable of supervising the work in your absence, seeing that needed materials and supplies are on hand, and, in general, making the work go forward. Naturally, you should select a man for this job who can work without close supervision. Make him understand what you expect of him, and be specific concerning the limits of his authority. For example, you should make clear to him that the specs for the job must be followed unless they are changed by higher authority.

JOB INSPECTIONS

Periodic inspections are one important method of ensuring proper quality of work done under your supervision. Let your men know that their work is likely to be inspected. When you make an inspection let the man or men concerned know how well or how poorly they did the job. A man's work is not likely to improve if he is not told specifically wherein his work needs improvement; and a man who has done in excellent job will be motivated to continue this level of work if you let him know that good work is noted and appreciated.

Examples of work which you should carefully inspect are installations of switch boxes and bends in conduit. A switch box may be installed perfectly as far as the electrical aspects are concerned but be poorly installed with respect to neatness of appearance. For instance, if the switch box is not placed deeply enough in the wall, it will be impossible to make the plate which covers the switch flush with the wall. A protruding plate gives the finish a rough appearance.

The bends in conduit which run to panel boxes and junction boxes should be uniform. Bends which are not uniform give a poor appearance and the impression of sloopy work. Impress upon your men that neatness, as well as technical correctness, is important in electrical work.

It is essential, of course, that work which you inspect conform to the electrical code and specifications for the job. Make certain that the work is technically correct, and then inspect for neatness.

SHOP SUPERVISION

For some overseas assignments, you will have to set up the electrical shop. The equipment and materials needed for the shop will be determined by higher authority before you leave the United States. The shop will normally require a test switchboard, megger, grinder, hydraulic pipe bender, power threaders, and other portable equipment necessary for electrical work. Large equipment such as bench lathes and coil winders are not normally necessary in the electrical shop; this type of equipment, however, will generally be available in a separate battalion machine shop or in a shop on the base to which you are deployed. The layout of your shop will depend upon the amount of equipment and the space which is available. During time of war, when a battalion would take a complete set of electrical equipment for the deployment, you would need to consult standard drawings shown in Advanced Base Drawings, NavDocks P-140. These drawings recommend layouts for various types and sizes of electrical repair shops at advanced bases.

Repair Parts

The main function of the electrical shop is to keep all electrical equipment for the battalion or detachment in first class working order. You will need an adequate stock of repair parts to do the job. These parts range from attachment plugs for small drill motors to parts for welding machines. The shop will also need miscellaneous items, such as lamps for replacement purposes.

Have a reliable man survey all electrical tools and equipment in the battalion, and then see that there are parts available to repair each

item. A quarter-inch drill that becomes inoperative because no repair part is available can cause as serious a delay as a larger piece of equipment which is out of commission.

A system of file cards will be necessary to keep track of the repair parts in stock. Place a man in charge of issuing parts and seeing that proper records are kept. When a part is used, it should be charged off on the card; when new parts are received, they should be added to the listing to show that they are on hand.

Work List

It is a good idea to make up a list showing the duties of each man assigned to the electrical shop. Such a list should show specifically the duties and responsibilities of each man and his assigned hours of work. Sometimes it will be necessary to work in shifts; advance notice to your men will enable them to plan their free time.

PASSING THE WORD

Passing the word is an important part of supervision. The battalion commanding officer, your company commander, and other higher authority frequently issue orders or directives which you should pass on to your men. You should be familar with all instructions and notices that affect your work and the work of your men and make certain that they have this information.

Orders and directives from higher authority may pertain to a particular job, recreation, liberty, military requirements, or safety. If the information is the type that you can pass orally, you should consider the best time to pass the word on. Morning quarters and special musters are often suitable times.

You will need to put certain types of information into writing in the form of a written directive. There is considerable personnel turnover in most units, and it takes a new man several weeks or months to learn about all policies. His task is even harder if there are no written directives to which he can refer. Safety requirements, local policies with respect to the use of Government material, tools and equipment, and local shop rules are examples of information which should normally be in written form.

SKETCHES

One technique of supervision that can save you time and trouble is the handmade sketch. When telling a man or group of men about some particular job or how to do a particular job, you will often find it useful to make a sketch of the job. If you turn the sketch over to the man, he can use it as a guide without having to rely completely on his memory. A sketch is also useful in helping a man understand points which are hard to explain orally. Encourage your men to ask questions after seeing a sketch to be certain that they understand exactly what you have in mind.

SAFETY

As a senior petty officer, your responsibilities for safety are considerable. Never overlook the safety factor in making a decision or giving an order; remember also that safety attitudes cannot be separated from safety practices. Use every practical method to make your men safety conscious.

Department of The Navy Precautions For Shore Activities. NAVSO P-2455 prescribes standard measures against the most common types of hazards which naval personnel are likely to encounter. One complete chapter discusses safety with respect to electricity and electronics equipment. You should become familiar with this publication. Remember, however, that the discussion in NAVSO P-2455 applies only to the most common hazards.

It is usually necessary to issue special precautions to cover local conditions and unusual circumstances. It is also necessary to keep a close watch to see that your men have the proper tools and clothing for each job on which they are working. There is a tendency for personnel to use clothing or tools that are handy, rather than going to some trouble to observe safety precautions. For instance, in splicing lead-covered cable, a man may find that no cotton gloves are handy when it comes time to wipe the joint; if a pair of leather-palmed gloves are handy, he may want to use them instead of the cotton ones. This man should be reminded that this is a dangerous practice; leather can transfer heat from the lead and cause a serious burn.

Other safety practices to follow during splicing include wearing goggles and high-top shoes and keeping sleeves rolled down.

SHOP SAFETY

There are numerous safety precautions that have particular application to shop work. See that your men follow them all. It is a good idea to list certain precautions which must be followed in the shop; safety posters may also be useful. Some important safety precautions for the shop follow.

See that men repairing electrical equipment at benches stand on a rubber mat or other approved insulating material.

Allow no electrical tools or equipment to leave the shop unless they have proper grounding facilities. In some localities, you may not have the three-wire grounding receptacles, which are required under safety regulations. If you are unable to get the three-wire receptacles, connect the third wire on the cord to a screw or bolt on a suitable ground.

Make certain that goggles are located near all bench tools which could cause an eye injury during use.

See that all shop machinery and equipment are kept free from oil, grease, carbon, dust, and dirt.

Allow no matches to be lighted or other open flames to be used in confined spaces containing combustible material.

Do not allow flammable liquids such as gasoline and benzene to be used as cleaning fluids on electrical equipment.

Use only rubber or insulating hose for blowing out equipment. Use no more than 50 pounds of pressure to avoid damage to insulation.

PAPERWORK

At the first class and chief levels your administrative duties will increase. With this increase will come additional paperwork-records, reports, instructions, and so forth. We have already mentioned the duties connected with scheduling of work, making and studying bills of material, and preparing directives.

It is absolutely essential for you to be systematic in keeping files and records. There may be a temptation to keep your administrative duties and responsibilities in your head; as work requests, reports, and publications pile up, however, you will find it necessary to arrange them so that each one is readily available when needed. Tossing papers on your desk or filing them carelessly in a drawer will eventually cause your records to become hopelessly fouled up. Try to keep your files in such a manner that the man who steps into your job can understand the status of all job assignments and work requests.

SUPPLY MATTERS

Most material which you require to do your job is issued after you have filled out the proper supply form. At some activities you will be authorized to sign this form; at others, it will have to be signed by an officer. Keep accurate records of what you order and when you receive it.

A record of tools and other equipment permanently assigned to you is kept on stock custody cards; you will have to sign for this equipment. Keep track of all items permanently assigned to your shop. Have anyone removing these items from the shop sign for them. Once a year, and whenever your company commander is relieved, you will have to take physical inventory of equipment assigned to you.

You may also have to fill out forms when a piece of equipment is to be SURVEYED. When a piece of equipment needs to be disposed of because of wear, irreparable damage, or because it is obsolete, a record must be made showing the condition of the material, the cause of the condition, the responsibility therefor, and the recommendation for disposition. An officer or a survey board must approve the request for survey. Your part in this procedure is to initiate the survey request. The request should contain complete information about the piece of equipment, why it should be surveyed where it is located, and other pertinent data.

WORK REPORTS

Daily time sheets are prepared for field projects showing the number of hours that each man puts in on a particular job. Figure 11-3 is a typical daily time sheet. The time sheet lists the name of each man in the work crew and indicates the number of hours he spent on particular jobs. The time sheet may indicate time lost through sickness, authorized absence, bad weather or other causes. As crew boss/ supervisor you must turn in the time sheet to

the project office or company office. When the time sheets from all the crews are in, they are checked for correctness and are forwarded to the battalion timekeeper for his records.

It is the responsibility of the crew boss to keep the operations officer up to date on the progress of the work his crew does on the project. This progress report may be done in many ways and is accomplished as the operations officer may direct.

"As-built" information is necessary on all construction projects and a crew boss is the best person to see to get the most accurate information. The operations officer may delegate a draftsman to receive the word from the crew bosses and keep the "as-builts" up to date.

CHAPTER 12

MAINTENANCE PROGRAMS

Efficient maintenance of public works and public utilities is vital to the economical functioning of the Navy's physical plant. As a CEl or CEC you may expect to be assigned maintenance duties either in a battalion or in a Public Works Department.

MAINTENANCE PUBLICATIONS

Maintenance programs and procedures are much less standardized in the battalions than in Public Works Departments. The PWDs follow the management principles and procedures set forth in Public Works Management Improvements, NavDocks P-99, and Maintenance Management of Public Works and Public Utilities, NavDocks P-321. The requirements for Continuous Inspection and for certain inspections and reports, as well as semitechnical data for the guidance of personnel who conduct the inspections and perform the maintenance, are presented in Inspection for Maintenance of Public Works and Public Utilities, NavDocks P-322. As a CEl or CEC you will probably be less concerned with NavDocks P-99 and NavDocks P-321 than with NavDocks P-322. Therefore, the latter part of this chapter contains significant excerpts from NavDocks P-322.

MAINTENANCE IN THE BATTALIONS

The maintenance program and procedures established at a battalion deployment site vary greatly depending on the military operational requirements and the permanency of the campsite. In some cases the battalion commanding officer may be solely responsible for establishing whatever maintenance procedures he sees fit. In other cases regiment, brigade, or ComCBPac or ComCBLant may direct the creation of certain maintenance programs and procedures. In any case, an effort is usually made to follow BuDocks procedures whenever the circumstances permit.

At semipermanent, or relatively permanent, campsites, maintenance reports and records may be established for the items of physical plant and utilities equipment which become relatively permanent fixtures and will probably not be carried away by the battalion after a short deployment.

The maintenance duties are generally carried out by the members of the shops company, which is usually B company. Inventory and maintenance records and reports are usually kept in the B company files. Reports of maintenance work performed, and, more particularly, the number of manhours expended on the work, are forwarded, usually in rough form, to the battalion operations office. Any smooth reports required by higher authority will usually be prepared at the battalion headquarters level.

At the end of a deployment the maintenance records for the camp are turned over to the relieving battalion. If the battalions do not make contact relief, the records may be delivered to the Public Works Department of a nearby naval activity to be held for the next battalion at the campsite.

Sometimes one or more items of physical plant may be provided for the Seabee camp by some nearby naval activity but be retained on the plant inventory of the Public Works Department. In this case, the maintenance records will usually also be kept by the Public Works Department and the inspection and maintenance will usually be performed by PWD personnel.

THE BUREAU OF YARDS AND DOCKS

Within the Department of the Navy, the Bureau of Yards and Docks is responsible for providing the technical guidance necessary to

see that the public works and public utilities at naval activities are properly planned, managed, and maintained. The Bureau also has certain material support functions which include responsiblity for the equipment for public works, public utilities, and transportation and construction. The Bureau operates under a policy of decentralization, and retains to the Bureau headquarters only a centralized control.

One of the major functions of the Bureau itself and the primary function of the field divisions is to provide assistance to the Public Works Officers stationed at the various Navy activities and installations. BuDocks provides assistance by promulgating policies and issuing directives concerning programs, management procedures, and so forth.

In the past few years certain District Public Works Offices (DPWOs) have been combined into divisions that serve larger geographical areas. Thus we have Area Public Works Offices (APWOs) and DPWOs combined into what are now known as Bureau Field Divisions (BFSs).

Field divisions work more directly with the individual activities, in that they help in implementing Bureau policies and programs, and also help the activity Public Works Departments in solving their particular problems. For small activities, the BFD can render services similar to those provided by a well-staffed engineering division at a larger activity. This relationship is indicated by the dashed line in figure 12-1 which shows technical guidance flowing from the BFD to the PWO.

The Bureau of Yards and Docks also is responsible for allocating to most activities the money needed for the operation and maintenance of public works and public utilities. This function is shown by the money line running from the BFD to the station CO. The amount of money allocated is determined through reports, requests, and on-the-spot observations made at the activity. The commanding officer of an activity is responsible for the proper management of funds allocated by the BFD for the operation and maintenance of public works and public utilities according to the rules prescribed by BuDocks. Note in the illustration that the PWO maintains technical liaison directly with the BFD, but that he gets his money through his commanding officer.

One relationship between the BFD and the PWO which is separate from any command relationship between the PWO and his commanding officer is that relating to the PWO's duties as an Officer in Charge of Construction or Resident Officer in Charge of Construction; in the discharge of these duties the PWO reports directly to the BFD.

THE PUBLIC WORKS DEPARTMENT

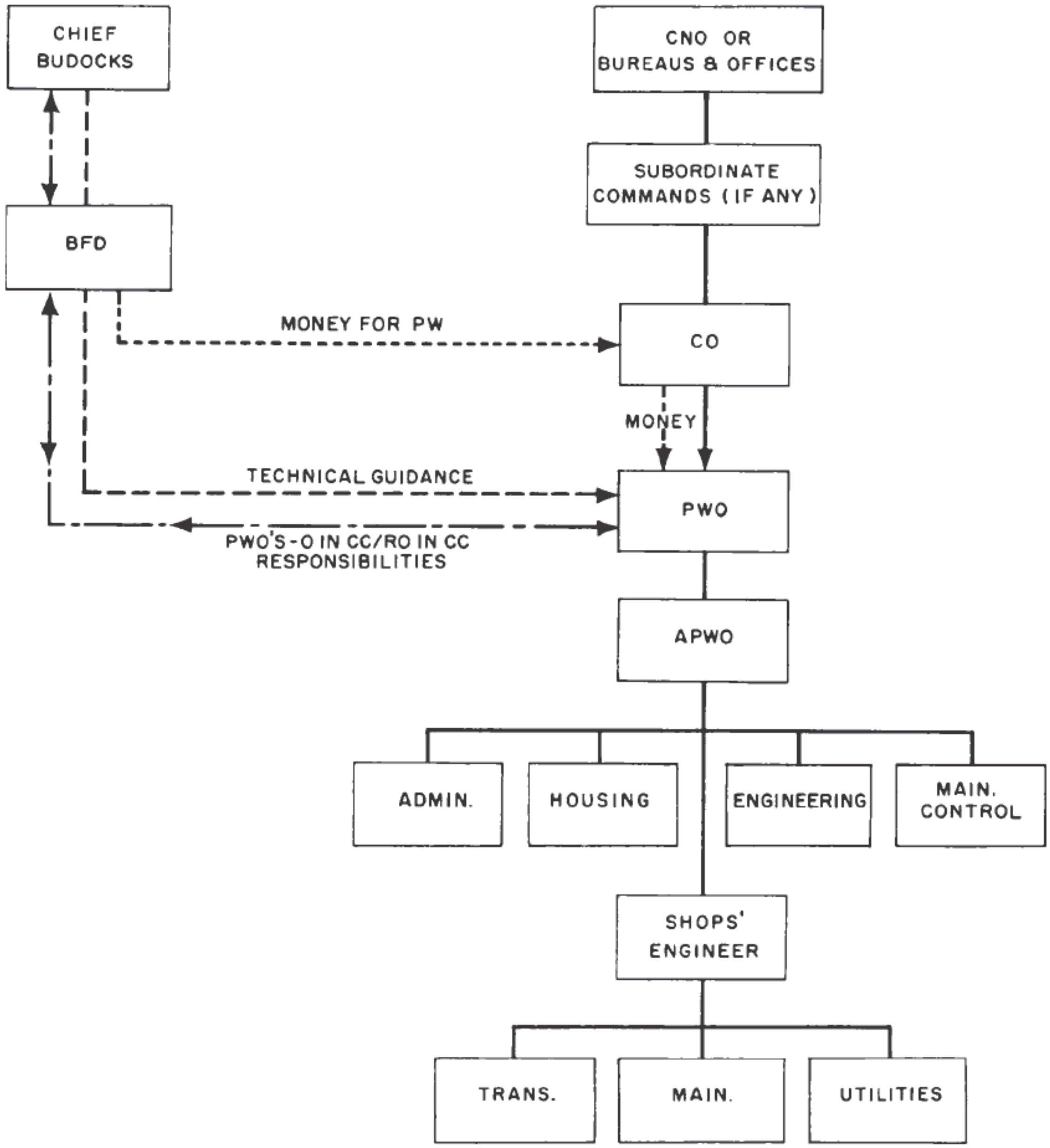
Figure 12-1 shows the standard Public Works Department organization recommended by BuDocks. The PWO is always an officer of the Civil Engineer Corps. The APSO and shops engineer (where the billets exist) are also CEC officers. Larger activities may have officers at the division level with titles such as maintenance officer, transportation officer, etc. The staffing of the PWD varies with the size, location, and needs of the activity. An activity with no family housing, for example, would obviously not need a housing division.

The administrative, housing, engineering, and maintenance control divisions are sometimes called the administrative and technical divisions and are usually staffed by civil servants called "GS" (for general schedule) or "white-collar" employees. The maintenance, utilities, and transportation divisions are sometimes called the operating divisions and are usually staffed by civil servants called "wage board" or "blue-collar" employees.

As a CEI or CEC, you may not normally expect to be assigned maintenance duties at large, well-established PWDs within metropolitan areas within the U.S.; the work will be performed by civilians. However, at overseas activities, at security activities, or at remote activities within the U.S., the situation is entirely different. As a CEI you may perform the functions of the utilities division director or maintenance division director. As a CEC you may perform the functions of the shops engineer or assistant public works officer at a small activity.

The Public Works Officer (PWO) specifically is responsible to the CO for providing adequate services at the lowest cost commensurate with the mission fulfillment and at the time and the place required to assure activity capability in meeting mission requirements.

The assistant public works officer/shops engineer is usually assigned responsibility for assuring that adequate public works services, including utilities, are provided. At smaller activities he provides direct supervision for



26.195

Figure 12-1.—Chain of command relationship.

day-to-day operations of, and coordination of all matters pertaining to, the operations of the maintenance, utilities, and transportation divisions. At larger activities, the latter responsibilities are delegated by the assistant PWO to the shops engineer, who in turn is held responsible for day-to-day supervision over the three operating divisions.

The Inspection Branch of the Public Works Department at large activities may be a separate branch but at small activities the shop personnel will have the inspection responsibility. The responsibilities of the branch include the performance of assigned inspections of public works and public utilities within established schedules and the preparation of inspection

reports reflecting physical condition of the plant, as well as the formulation of recommendations and descriptions of repair work required.

CONTINUOUS INSPECTION

The continuous inspection is an essential requirement of controlled maintenance. The purpose of continuous inspection is to identify deficiencies in public works and public utilities and to initiate corrective action that will bring these facilities, or parts of facilities, up to the maintenance standard. Inspection should be planned for (1) the detection of maintenance deficiencies in the early stages of development, (2) a reduction in the number of breakdowns and in the cost of repairs, (3) the provision of a more constant flow of work to the operating divisions, (4) improved utilization of labor and determination of material requirements, and (5) for detection and reduction of overmaintenance.

Continuous inspection deals only with existing facilities. It does not include requirements for new construction, alterations, or improvements that may be considered desirable or necessary as a result of changes in the mission of the activity or changes in operational or maintenance procedures.

Categories of Inspection

The three categories of inspection in continuous inspection are operator inspection, preventive maintenance inspection, and control inspection. These three categories are illustrated in figure 12-2.

Operator Inspection

The operator inspection consists of examination, lubrication, and minor adjustments of equipment and systems for which the public works officer is responsible and which a specific operator is assigned.

An example of this would be a power plant that furnishes all the electrical power for a facility.

The operator responsibility for inspection falls on the person assigned to the equipment or system. Instructions should be posted on equipment or posted in the watch log. Breakdowns and deficiencies beyond the capacity or authority of the operator should be reported to the supervisor immediately. The inspection branch reviews reported deficiencies, initiates further action if it is required, and evaluates, at the time of control inspection, the effectiveness of operator inspection.

Inspection Record System

The inspection record system is a collection of forms, devices, and procedures with which effective continuous inspection can be controlled with the minimum of time, money, and manpower. It should be clearly understood that the purpose of the inspection record system is to do a job in an easy manner, and to use only those forms, procedures, and records that effect those parts that are considered necessary for their installation. It is not intended to generate records if there is no use made of the records. If or when a first or chief CE may become responsible for establishing an inspection record system, assistance may be obtained from your Bureau Field Division.

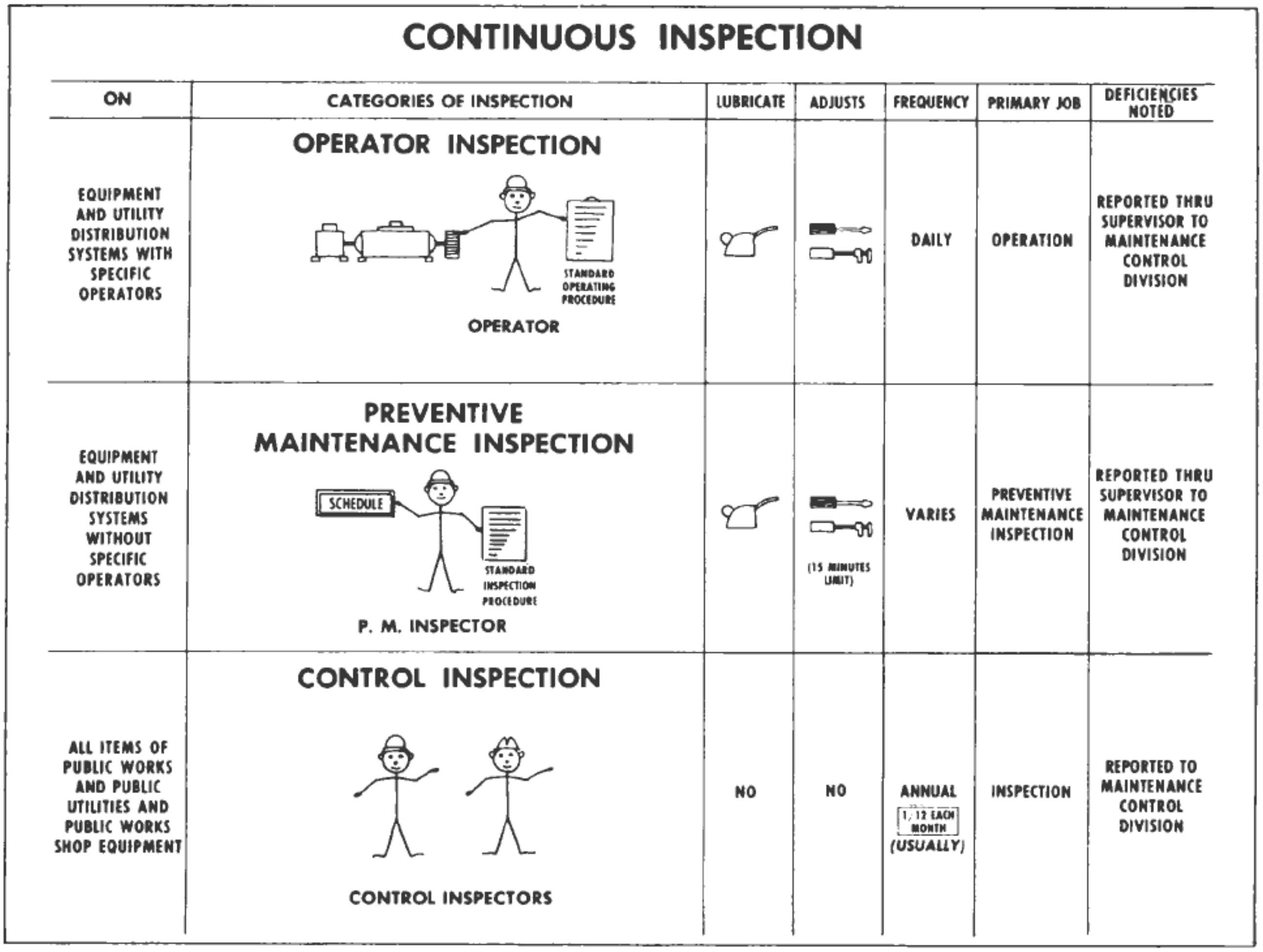
Inventory

An inventory of all items of public works and public utilities is part of the foundation of controlled maintenance. A part of the inventory information is available from plant account records and from the shore facilities planning system. Neither will supply sufficient information on all items. The items that do not show up in these records can be picked up by the inspectors during their initial inspections; modifications must then be made in the inspection schedule as their data is refined. Figure 12-3 illustrates an inventory record form which may be used to record a complete inventory of items under the cognizance of the public works officer.

Data record sheets are used to record the key physical characteristics of the various items of public works and public utilities. These sheets, as shown in figure 12-4, should be completed by the maintenance control division and retained for reference by inspectors, planners and estimators. These sheets can be filled out by the inspectors as an added assignment while they make their scheduled inspections over a period of time.

Scheduling of Inspections

There are several factors that have to be considered for economical performance of



26.196

Figure 12-2.—Categories of inspection.

continuous inspection. It requires a schedule of inspection based on the inventory of items of public works and public utilities. Too-frequent inspection can be a waste of manpower and could lead to overmaintenance while infrequent inspection will result in undermaintenance and large repair or replacement projects.

Frequencies of inspections and tests should be based on local weather conditions, age of the item, use (including severity of use), and other local factors considered pertinent.

The following is a simple guide that could help determine the frequency of inspection. Ask the following questions:

1. Will the failure of this item interfere with an essential operation of the naval activity?

2. Does the item have a high cost or a long lead time for replacement?

3. Will failure endanger life and/or property?

If all the questions are answered yes there must be frequent inspections and the very best plan of maintenance that can be devised. For example: an item that could cause a shutdown of all operations in a building or shop and would endanger life and property because of the failure of an item. If the answer is yes and no an item would require attention but not to the degree as mentioned before. If the answer is no, the items could be put into an even lesser group for inspection.

One of the best ways to establish frequency of inspection is to check the manufacturer's

INVENTORY RECORD NAVDOCKS 2500 (9-57) MADE BY H.C. Jones DATE 10 JAN 1959

PROPERTY NO.	LOCATION	DESCRIPTION	MANUFACTURER	MFGR. SERIAL NO.	AGE	COST		
175	II-B-6	OFFICE BLDG						
123001127	175-11	AIR CONDITIONER-WINDOW	MCGRAW ELECTRIC	20336764	NEW			
123001247	175-1-1	✓ ✓ ✓	✓ ✓	2033892	✓			
——	175-1-2	✓ ✓ - 5 HP	CHRYSLER	4154				
——	175-1-3	✓ ✓ ✓	✓	3872				
123010908	175-1-4	WATER COOLER	SUN ROC	309765				
123001242	175-1-6	AIR CONDITIONER-WINDOW	FEDDERS	245382	NEW			
123001241	175-1-7	✓ ✓ ✓	✓	251122	✓			
——	175-1-8	✓ ✓ - 5 HP	CHRYSLER	4026				
123112742	175-1-8	TABLE SAW 10"	DELTA	49682				
123112743	175-1-8	DRILL PRESS 12"	DELTA	75687				
123112744	175-1-8	PLANER 6"	SEARS ROEBUCK	24352				
——	175-1-9	HOT WATER HEATER - GAS	BRYANT	1479862				
123010948	175-1-10	WATER COOLER	SUN ROC	301426				
——	175-2-1	AIR CONDITIONER - 5 HP	CHRYSLER	3319				
——	175-2-2	EXHAUST FAN - 30"	HUNTER	142786				
123010947	175-2-3	WATER COOLER	SUN ROC	301427				
123001236	175-2-4	AIR CONDITIONER-WINDOW	FEDDERS	244197	NEW			
123001238	175-2-5	✓ ✓ ✓	✓	245102	✓			

26.197

Figure 12-3.—Inventory record.

publications and operating personnel should be consulted in establishing inspection frequency.

On certain types of low cost or inaccessible items, replacment of the item at the time of breakdown may be more economical than continuous inspection. When it is determined that replacement is economical, periodic inspections are not warranted. For example: household type refrigerator sealed units, fractional horsepower motors, and drinking fountain refrigeration sealed units are a few items that may be more economical to replace than repair.

The general steps to be taken in preparing an inspection schedule are shown in figure 12-5, flowchart for scheduling inspections. These steps are applicable, in general, to both preventive maintenance inspection and control inspection. The procedures and forms have been developed to provide a maximum of control and information with a minimum of effort.

The inspection checkoff card is for use of the inspector to record the results of his inspection. The card shown in figure 12-6 is the NavDocks 2501 form. This form is provided in two colors, green for control inspection and buff for preventive maintenance inspections. The card is arranged to record the condition of one to forty-eight check points by varying the number of lines used for each inspection. One to sixteen check points require one line, seventeen to thirty-two check points require two lines, and thirty-three to forty-eight check points require three lines. Check points are identified and described in the inspection guides and each inspection checkoff

DATA RECORD SHEET - TRANSFORMERS NAVDOCKS 2533 (9-87)

TRANSFORMERS	1	2	3
KVA	25	25	25
PHASE	✓ 1 ☐ 3	✓ 1 ☐ 3	✓ 1 ☐ 3
PRIMARY VOLTS	13,200	13,200	13,200
SECONDARY VOLTS	120/208	120/208	120/208
CYCLES	☐ 25 ✓ 60 ☐ 50	☐ 25 ✓ 60 ☐ 50	☐ 25 ✓ 60 ☐ 50
IMPEDANCE %	5.2	5.2	5.2
RATED TEMP. RISE °C	55	55	55
IS TRANSFORMER COMPLETELY SELF PROTECTED	☐ YES ✓ NO	☐ YES ✓ NO	☐ YES ✓ NO
MFR.	ACME	OMEGA	ACME
MFR. SERIAL NO.	1247	375	1249
MFR. TYPE NO.	L	K	L
TYPE	☐ INDOOR ✓ OUTDOOR ☐ SUBMERSIBLE ☐ DRY	☐ INDOOR ✓ OUTDOOR ☐ SUBMERSIBLE ☐ DRY	☐ INDOOR ✓ OUTDOOR ☐ SUBMERSIBLE ☐ DRY
MOUNTING	☐ PAD ✓ PLATFORM ☐ POLE ☐ WALL	☐ PAD ✓ PLATFORM ☐ POLE ☐ WALL	☐ PAD ✓ PLATFORM ☐ POLE ☐ WALL
FILLING — TYPE MINERAL OIL	✓	✓	✓
FILLING — TYPE ASKAREL			
FILLING — QUANTITY GAL.	19½	19½	19½
TAPS — NO. AND % ABOVE NORMAL	2-2½	2-2½	2-2½
TAPS — NO. AND % BELOW NORMAL	2-2½	2-2½	2-2½
COOLING — AIR — SELF			
COOLING — AIR — FORCED			
COOLING — AIR — SELF/FORCED			
COOLING — OIL — SELF	✓	✓	✓
COOLING — OIL — FORCED			
COOLING — OIL — SELF/FORCED			
COOLING — OTHER			

CATEGORY CODE	81210
DATE OF SHEET	12 JUNE 1957
BANK NO.	3
BANK KVA	75
DATE INSTALLED	1945
CORRECTION	☐ PARALLEL ☐ DELTA-DELTA ☐ OPEN-DELTA ☐ WYE-DELTA ☒ DELTA-WYE ☐ WYE-WYE ☐ OTHER

PROTECTIVE DEVICE — TRANSFORMER	1	2	3
FUSE-AMPS	5	5	5
CIRCUIT BREAKER — RATING-VOLTS			
CIRCUIT BREAKER — RATING-AMPS			
CIRCUIT BREAKER — INTERRUPTING CAPACITY			
CIRCUIT BREAKER — MFR.			
CIRCUIT BREAKER — MFR. SERIAL NO.			
LIGHTNING ARRESTER — INTEGRAL	☐ YES ☐ NO	☐ YES ☐ NO	☐ YES ☐ NO
LIGHTNING ARRESTER — EXTERNAL	✓ YES ☐ NO	✓ YES ☐ NO	✓ YES ☐ NO
LIGHTNING ARRESTER — MFR.	ACME	ACME	ACME
LIGHTNING ARRESTER — MFR. SERIAL NO.			
DIFFERENTIAL RELAYS — INSTALLED	☐ YES ✓ NO	☐ YES ✓ NO	☐ YES ✓ NO
DIFFERENTIAL RELAYS — MFR.			
DIFFERENTIAL RELAYS — MFR. SERIAL NO.			

PROPERTY NO.	BUILDING OR LOCATION		ACTIVITY
261200,01,02	II-B-17	TRANSFORMER	N.S. Anywhere

U. S. GOVERNMENT PRINTING OFFICE

26.198

Figure 12-4.—Data record sheet.

card must identify the required inspection guide. It should be noted that an operator or preventive maintenance inspection is always followed by a control inspection.

Performance of Inspections

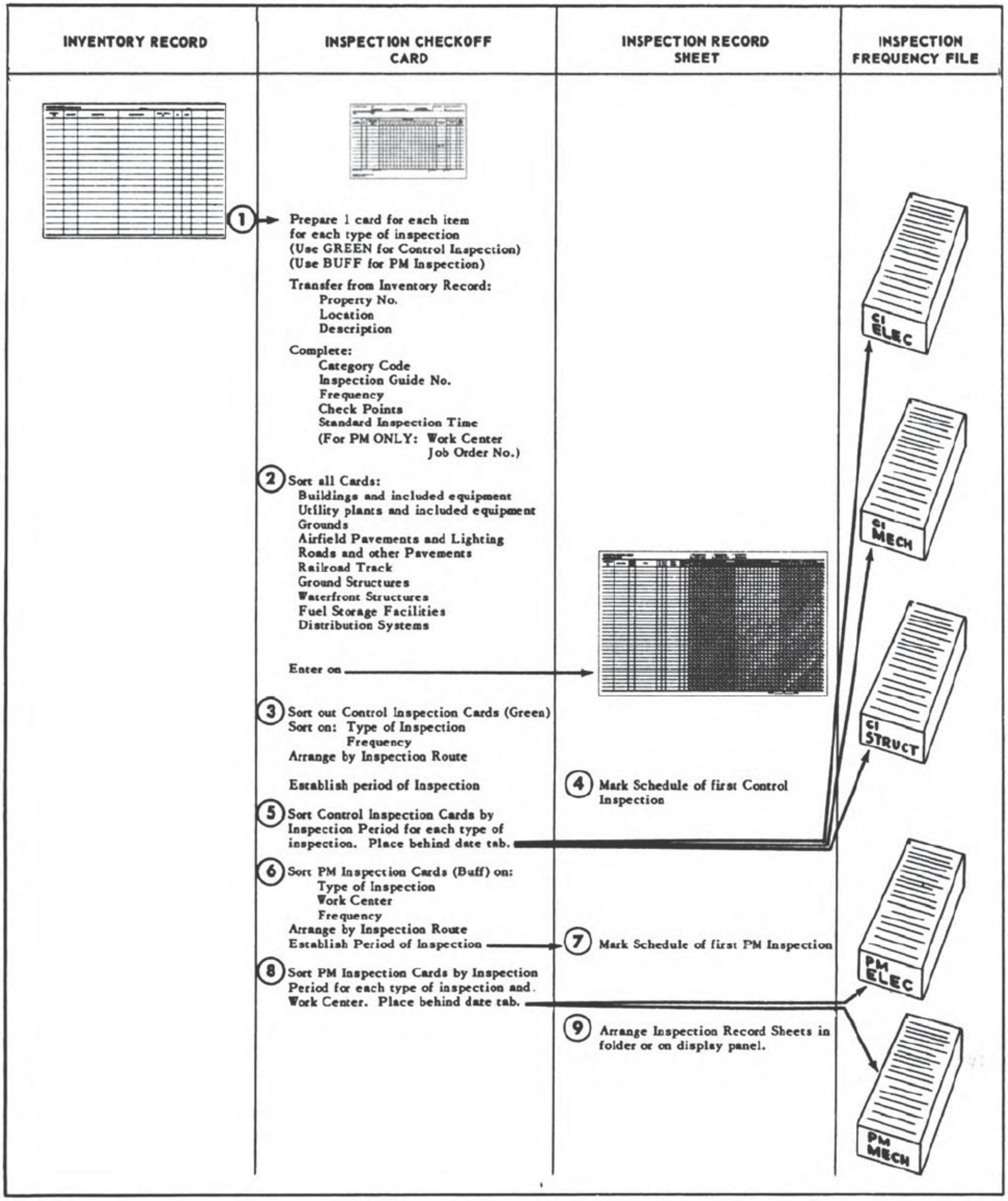
The source of inspectors depends upon the quality and experience of the personnel selected to make the various inspections. Inspection at naval activities should be made by qualified personnel on the rolls of the activity, except:

1. Where inspection responsibility has been assigned to the commanding officer of a Public Works Center.

2. Where commanding officer of major activities are responsible for performing the maintenance of public works and public utilities at adjacent activities.

3. Where it is impracticable for activity personnel, because of lack of experience or capability, to perform inspections on certain types of equipment or structures, or where it may be impracticable to employ qualified personnel for such inspections because of limited workload.

The inspectors selected should be conscientious and extremely careful in their observations. Enough time should be taken to make the examination thorough in every way and the conclusions should be reached only on basis of actual observation and analysis, not from reports of others. Inspectors shall make every effort to determine of any deficiency when



26.199

Figure 12-5.—Flow chart for scheduling inspections.

USE INSPECTION GUIDE S-2

CODE: NI NOT INSPECTED; ✓ SATISFACTORY; X ADJUSTMENT REQUIRED; (X) ADJUSTMENT ACCOMPLISHED; — NOT APPLICABLE; XX REPAIRS REQUIRED; (XX) REPAIRS ACCOMPLISHED

WORK CENTER

CHARGE PM INSPECTION TO 10

FACTORS AFFECTING INSPECTION

KEYS TOOLS ICE PICK, HAMMER

GPO : 1958 O - 452140

DATE INSPECTED	FREQ	CHECK POINTS SCHEDULED FOR INSPECTION	1 17 33	2 18 34	3 19 35	4 20 36	5 21 37	6 22 38	7 23 39	8 24 40	9 25 41	10 26 42	11 27 43	12 28 44	13 29 45	14 30 46	15 31 47	16 32 48	INSPECTOR'S INITIALS	INSPECTION HOURS STD	INSPECTION HOURS USED	DEFICIENCY REPORT MADE YES	DEFICIENCY REPORT MADE NO
2/2 JUN	A	1-47	✓	-	-	✓	✓	X	-	-	-	-	X	-	-	-	✓	✓		4			
			✓	X	✓	✓	-	-	-	✓	✓	✓	✓	✓	✓	✓	✓	✓					
25 JUN 58			-	✓	-	✓	-	✓	-	✓	-	-	-	-	✓	✓	✓		DBC		4½	✓	

PROPERTY NO 150 DESCRIPTION MESS HALL AND GALLEY CATEGORY CODE 72310 LOCATION II-C-18

26.200

Figure 12-6.—Inspection checkoff card control inspection.

one is indicated. The apparent cause is not always the true cause and may only be a secondary reaction or manifestation of the true cause. Inspectors shall consider defects carefully to determine the relation to, or influence on, the safety of the facilities.

Inspectors shall make a general observation of the condition of the facilities or equipment, as well as of the attendants, as a guide in forming an opinion of the general care of the facilities or equipment.

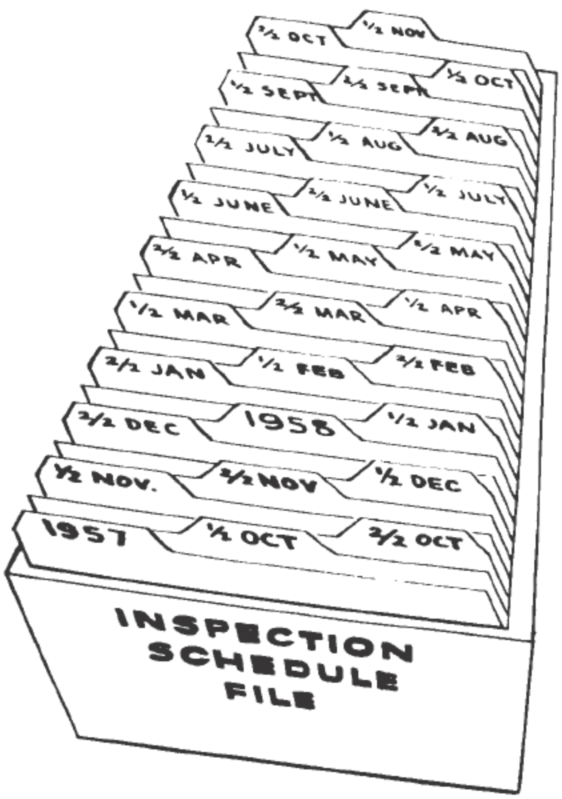
NavDocks P-322 says that appropriate protective equipment, such as safety glasses, hard hats, gloves, safety belts and the like should be provided to each inspector on a permanent custody basis. The inspectors shall observe the proper safety precautions while conducting inspections and tests not only to avoid hazards to themselves, but also to avoid hazards to others. Conditions resulting in accidents are created, in most cases, by the personnel involved. Other references on safety precautions include Department of the Navy Safety Precautions for Shore Activities, NavSo P-2455, the National Electrical Code, and the National Electrical Safety Code.

Inspectors should be carefully instructed concerning the duties expected of them, and they should be held strictly responsible for conducting a thorough and workmanlike inspection of all units and facilities assigned. Inspectors should request technical assistance when they doubt the sufficiency of their judgment in particular cases. Control inspectors should be cautioned that they shall not make adjustments nor perform repair work unless the inspection guide specifically states that he is to do so.

Files

Inspection checkoff cards are kept in an inspection frequency file pending use by the inspector. A minimum of one file is recommended for each type of inspection for both control inspection and preventive maintenance inspection. Additional files under each type, for each inspector, may be established if considered desirable. Each file consists of a series of yearly division tab card separators

and two sets of semimonthly division tab card separators. Figure 12-7 shows a suggested arrangement. Placement of the semimonthly tab card separators will depend upon the period in which the file is started. The file is located in the inspection branch. The purpose of the file is to provide an easy and rapid means of scheduling inspections.



6.17

Figure 12-7.—Inspection schedule file.

The inspection record file is the collection of the inspection record sheets on which the inspection schedule is recorded. The file may be either a notebook type or a display panel type. The file should be located near the supervisor of the inspection branch. The reason for this file is to keep a record of the inspections scheduled and completed readily available.

The suspense file, is developed from inspector's report, which contains reported items of maintenance and repair (essential maintenance), items of projected maintenance or items for reactivation. The purpose of the file is to keep these maintenance items readily available for use in making reports and annual inspection summaries and for ease in checking them off when funds become available and the required work is authorized or performed.

There should be a file of completed job orders filed in sequence of order number by year of issue. The file is used for reference purposes. Current instructions on records disposal tell how completed job orders are disposed of.

A completed emergency or service work authorization file is kept for reference purposes. Examples of use:

1. the repetitive type failures or deficiencies
2. the frequency of emergency service work reported by sources other than inspectors for comparison to the inspection frequency
3. the quantity and type of labor required to perform the work, and such other analyses found desirable.

Specialized Inspections

The purpose of specialized inspection is to determine (1) that all components are kept in a safe, properly maintained, and operating condition and (2) that they have not been altered except where approved by responsible authority.

The inspections are based on the safety code requirements for the item, inspector's manual and supplements. Some items the special inspections cover are elevators, platform lifts, dumbwaiters, and escalators.

The maximum frequency between inspections and tests, vary from quarterly to five years for inspections and test range over a period of yearly to six years. Part B section eight of NavDocks P-322 has tables for inspection frequencies.

All personnel performing the specialized inspections and tests, other than preventive maintenance inspection, on elevators, lifts, dumbwaiters, and escalators shall have possession of experience and training commensurate with appropriate U.S. Civil Service standards. Contract personnel shall have a certification to inspect elevators by a licensing authority of a political subdivision, such as state, province, territory, county, city, of the United States or Canada. When qualified personnel cannot be acquired locally an inspection may be requested from the next senior BuDocks office.

When deficiencies are found necessary, action for correction shall be initiated promptly. Also, when deficiencies are found but do not detract from operating safety, the inspection

certificate may be issued prior to the correction of the troubles found.

Boilers and unfired pressure vessels are another area of inspections and testing under specialized inspections. The NavDocks inspection report-boilers form is filled out as illustrated in figure 12-8, forwarded to the Bureau of Yards and Docks Code M-500. If contract personnel carry out the inspection and tests, activity or staff personnel prepare these reports to be forwarded. If any deficiencies are found, the necessary action to correct them should be initiated promptly by the activity.

INSPECTION GUIDES

The inspection guides are volumes 2, 3, and 4 of the NavDocks P-322. Volume two is the electrical, volume three the mechanical, and volume four is the structural guides used in conjunction with volume one.

Volumes 2, 3, and 4 provide a number of Inspection Guides that may be utilized by the activities of the Shore Establishment in conducting Continuous Inspection. These guides are primarily directed to those inspectors performing Preventive Maintenance and Control Inspections, and are for their use and reference. The guides contain the essential technical, semi-technical, and practical information considered necessary to conduct a thorough and productive inspection of a unit or facility in an active status.

The inspection guides are arranged on perforated cards for easy removal and use in the Inspector's Folder. The guides are designed on a "check point" basis to simplify the use of the Inspection Checkoff Card. The number for each check point on the guide has a corresponding number on the Inspection Checkoff Card. Each check point indicates the conditions, or deficiencies to be reported (those below the maintenance standard), the adjustments or repairs to be made, and, in some cases, the manner in which the inspection, examination, or test is to be conducted. Where possible, space has been provided to allow the use of additional check points found desirable or necessary.

Following the check points are paragraphs indicating scope of the guide, safety precautions, and reference material.

The guides are developed on the basis of continuous use of the unit or facility in an active status for the maintenance standard given in Part E. When the unit or facility is not continuously utilized the inspection guides should be modified to conform to the maintenance standard for that status. Upon mobilization the maintenance standards are to be modified, and the use of the inspection guides shall be modified to conform to the intent of the mobilization standards.

The electrical and mechanical guides, Volumes 2 and 3 which are generally used for both Preventive Maintenance Inspections and Control Inspections show adjustments and repair work to be done by the Inspector. The Control Inspector shall not make adjustments or perform repair work unless the guide specifically states that he is to do so. The Control Inspector should, however, report this work for performance if it should be necessary. The Table of Inspection Frequencies in Appendix A indicates those items considered suitable for Preventive Maintenance Inspection, subject to activity determination.

Sometimes reference is made in the guides to manufacturer's instructions or publications. Personnel concerned with operation, inspection, and maintenance of equipment should become familiar with the manufacturers' instructions and recommendations. The location of such documents should be known and available to these personnel. Prior to inspection, the inspector should refresh his memory by reviewing the pertinent instructions.

Additions and Changes

Due to the flexibility of the subject matter involved, and the wide range of individual items covered, a publication of this nature cannot remain static, and must be revised periodically to include new methods and procedures for efficient inspection of the multitude of items currently in use by the Shore Establishment. Much of this new information must be expected to originate at activity public works department level, where Continuous Inspection is in operation. Therefore, the assistance of the activity public works personnel is solicited to keep this publication current and adequate. When new guides, methods, or procedures of inspection are developed, it is requested that such information be forwarded to the Bureau of Yards and Docks, Code M-200, via the cognizant Director, Overseas Division or District or Area Public Works Officer, for

INSPECTION REPORT - BOILERS
NAVDOCKS 2544 (REV. 11-60)

Instructions for completing form are contained in Paragraph 88.02 of NAVDOCKS P-322

REPORT BUDOCKS 11014-11

1. FROM: CO NAVSTA "X"
2. DATE OF REPORT: 20 June 1961
3. TO: DPWO 2ND
4. DATE OF INSPECTION: 16 June 1961
5. MANUFACTURER: Bobcock & Wilcox
6. INSPECTION OR TEST: [X] EXTERNAL [X] INTERNAL [X] HYDROSTATIC [X] OPERATION
7. PROPERTY NO.: 205
8. MFGR. SERIAL NO.: 132428
9. MFGRS. MODEL NO.: FF
10. BUILDING: 8
11. YEAR BUILT: 1944
12. YEAR INSTALLED: 1945
13. BOILER
    - TYPE: [ ] C.I. [X] STEEL [X] WATER TUBE [ ] FIRE TUBE
    - DRAFT: [ ] NATURAL [X] FORCED [X] INDUCED
    - PRODUCES: [X] STEAM [ ] LOW TEMP. WATER [ ] HIGH TEMP. WATER
    - CIRCULATION: [X] NATURAL [ ] FORCED
14. CAPACITY (Indicate measure): 40 — [X] M LB/HR [ ] M BTU/HR
15. USE: [X] EXPORT [ ] ELECTRIC POWER GENERATION [ ] LAID UP - WET [ ] LAID UP - DRY
16. INSPECTION CERTIFICATE: [X] POSTED [ ] NOT POSTED
17. WAS BOILER PREPARED FOR INSPECTION PRIOR TO ARRIVAL OF INSPECTOR: [X] YES [ ] NO
18. COMBUSTION CONTROL: [X] AUTOMATIC [ ] SEMI-AUTOMATIC [ ] MANUAL [X] OPERATING [ ] NOT OPERATING CO_2 12.8
19. BOILER FEEDWATER TREATMENT — *In accordance with Chapter 4, NAVDOCKS TP-PU-3* — [ ] SATISFACTORY [X] UNSATISFACTORY

PRESSURE (psig)

20. MAXIMUM ALLOWANCE WORKING PRESSURE	21. NORMAL OPERATING PRESSURE	22. TEST PRESSURE	23. SAFETY VALVE
160	125	240	150

24. FLUE GAS OUTLET TEMPERATURE: AFTER BOILER 478 °F; AFTER HEAT TRAP None °F
25. OPERATING TEMPERATURE AT SUPERHEATER OUTLET: Sat. °F

26. **CONDITION** *(S = Satisfactory, U = Unsatisfactory)*

ITEM	S	U	ITEM	S	U	ITEM	S	U
1. WATER COLUMNS	X		12. SUPERHEATERS			23. SCALE		X
2. GAGE GLASSES		X	13. ECONOMIZERS			24. CORROSION	X	
3. GAGE COCKS	X		14. AIR HEATERS			25. PITTING	X	
4. BLOWDOWN VALVES & COCKS	X		15. SEAMS	X		26. CRACKS	X	
5. FEEDWATER VALVES	X		16. TUBE ENDS	X		27. LAMINATIONS	X	
6. STEAM PRESSURE GAGE	X		17. TUBE SHEETS	X		28. EVIDENCE OF OVERHEATING	X	
7. FEEDWATER REGULATOR & CONTROLS	X		18. RIVETS	X		29. LEAKING	X	
8. COMBUSTION CONTROLS	X		19. STAY BOLTS	X		30. SOOT	X	
9. FD & ID DAMPERS	X		20. BRICKWORK		X	31. EXCESSIVE ACCUMULATIONS	X	
10. BOILER CONNECTIONS	X		21. WATER WALL	X		32.		
11. SAFETY VALVES	X		22.			33.		

FUEL	COAL							OIL			GAS
FIRING EQUIPMENT	SPREADER		UNDER FEED		CHAIN GRATE	PUL-VERIZED	HAND FIRED	STEAM ATOMIZED	ROTARY CUP	OTHER	
	M.S.	D.G.	M.R.	S.R.							
27. TYPE								X			
28. CONDITION								S			

Any Special comment, explanations, recommendations, or statements as to corrective action taken or to be taken are to be made on blank sheets, and attached hereto.

29. ATTACHMENT: X COPY OF INSPECTOR'S REPORT; SPECIAL COMMENT
30. COPY FOR: X BUDOCKS (M-500)
31. SIGNATURE: O. Board. — O. Board, BY DIRECTION

8-20688

26.201

Figure 12-8.—Inspection report-boilers.

review and possible dissemination to the entire Shore Establishment.

ANNUAL INSPECTION SUMMARIES

The annual inspection summary is established to provide information to the Bureau of Yards and Docks and to the cognizant sponsor or supporting bureau, or its field representative, as to deficiencies in existing buildings, structures, or facilities. Also, the annual inspection summary provides military commands with information on the physical condition of an activity based upon the maintenance standard for that activity. The summaries are not requests for funds. Funds to correct deficiencies indicated shall be requested, where necessary, in accordance with applicable directives issued by the various bureaus and offices of the Navy Department.

In order to provide suitable coverage to the property in which the navy has an interest, five types of annual inspection summaries have been developed. The type of summary to be used depends upon the type of property under consideration. The details that is in each summary will be covered later in this chapter.

Control Sheets

The control sheet of annual inspection summaries is a two part report which provides a uniform system of recording the status of inspection summaries. For type "A" summaries it indicates the dollar value of the backlog of essential maintenance. For other summaries it will assist in the scheduling of facilities for inspection by staff personnel of the BuDocks division director of the district.

The report shall be prepared only by BuDocks Field Division Directors. This report is prepared in two separate parts and forwarded.

Part 1. One part of the report shall list only that property for which type "A" and type "E" annual inspection summaries are required. This report is prepared as of 30 June each year and shall be forwarded to reach the bureau of yards and Docks by the following 1 September. Two copies of the report shall be furnished together with copies of those type "A" and type "E" annual inspection summaries required to be prepared as of 30 June.

Part 2. The other part of the report shall list that property for which type "B", "C" or "D ' annual inspection summaries are required. Two copies of this report will be forwarded to reach the Bureau of Yards and Docks by the 10th day of August each year.

Type "A" Summary

A type "A" summary shall be used to report conditions for the following types of property:

1. Property on the plant account of an activity of the shore establishment, regardless of operational status. No summary is required where the properties are leased from others, or occupancy is on the basis of a permit from another government agency.

2. Navy owned facilities, not a part of a naval activity, which are operated under a facilities contract by contractors in the performance of research and development.

A type "A" summary shall be prepared by, or based on inspections performed by activities required to submit controlled maintenance management reports, annually as of 30 June. These summaries shall be forwarded to reach the appropriate division director, or district not later than 1 August.

Type "B" Summary

The type "B" summaries are used to report conditions for the following type of property:

1. Naval property, not including industrial facilities which is outleased or outpermitted to others.

2. Naval property, which has been declared excess or surplus and is pending lease, transfer or sale and for which the Navy is responsible for protection and maintenance and repair until such time that the responsibility is transferred to the disposal agency.

3. Naval property not including industrial facilities, which has been sold or transferred with a provision for recapture in event of a national emergency.

4. Sponsor operated Title VIII (wherry) housing projects.

Annual reports at not more than 12 month intervals, for the property described in type "B" paragraph 4 and those portions of paragraph 2 which are in the custody of the Bureau of Yards and Docks, are submitted. Only upon request are reports submitted for property covered in paragraph 3 and portions of paragraph 2 that is not in the custody of the Bureau of Yards and Docks.

The Bureau Field Division director is responsible for preparing and forwarding to the Chief, Bureau of Yards and Docks, the report. The only exception is the Title VIII (wherry) housing projects. The summary will be prepared and forwarded to the Chief, Bureau of Yards and Docks, by the commanding officer designated in the lease.

Type "C" Summary

A type "C" Summary shall be used to report conditions for the following types of property:

1. Navy-owned Industrial Facilities which, during peacetime are leased, with termination provisions, for civilian operation; are maintained as an unused standby; or are being operated under a facilities contract.

2. Privately owned industrial plants (part of the Departmental Plant Reserve) in which the Navy has a legal right, through the National Security Clause or similar provisions, to occupancy, use, or priority for production, if needed.

3. National Industrial Plant Reserve plants.

The type "C" summary is submitted as follows:

1. Annually, at not more than 12-month intervals, for property described in paragraph 1., when the Bureau of Yards and Docks is charged with the responsibility for inspection and maintenance.

2. Upon request of the cognizant management bureau, or its field representative, for all other property. When a cognizant management bureau, or its field representative, has previously requested that an inspection of property under its cognizance be made, and the request is not limited to a one-time inspection, the District Public Works Officer shall submit summaries at not more than 12-month intervals.

3. Annual Inspection Summaries shall be forwarded to reach the cognizant management bureau prior to 1 September of each year.

The Summary shall be prepared by the Bureau Field Division director. Proper performance of the inspection and preparation and forwarding of the Summary requires close coordination and cooperation between two organizational components of the BFD, the Maintenance Planning and Evaluation Section and the Naval Industrial Reserve Facilities Branch.

Type "D" Summary

A type "D" summary shall be used to report material inspection of floating drydocks in the following categories.

1. Civilian-manned docks under the cognizance of naval shore activities.

2. Docks outleased under NOy or NBy contract.

The type "D" summary is not required for military manned or inactive floating drydocks or for floating drydocks recapturable under the national security clause unless so determined by the command or administrator concerned. In such cases, the composition of the inspection board and the requirements for submission of the summary shall be as directed by the command or administrator concerned.

Inspections shall be made annually, at not more than 12 month intervals. When the inspection is made by the board of inspection and survey, the annual inspection summary for that period is not required.

The summary will be prepared and signed by the inspection board, and forwarded to the appointing authority.

Type "E" Summary

A Type "E" Summary shall be used to report deficiencies in the following types of family housing constructed or acquired under Title VIII of the National Housing Act, as amended:

1. Capehart

2. Wherry - Navy owned and operated.

The family quarters acquired under the provisions of Title VIII of the National Housing Act, as amended, involve assumption and/or guarantee of long-term mortgage obligations by the Department of the Navy. These obligations will be funded over the years from the quarters allowances forfeited through continuous operation of the quarters. The mortgaged premises of these housing projects must, therefore, be kept in an adequate state of repair to obtain full utilization of the quarters for the period required to liquidate the mortgage indebtedness.

Summaries shall be submitted annually, at the same time that the Type "A" Summary is submitted for the activity.

The summary shall be prepared and submitted by the command responsible for the maintenance and operation of the housing facilities reported on. The summary shall be forwarded via the appropriate BFDD who shall provide an endorsement as to the propriety of the deficiencies listed and the completeness of the report. If considered necessary, spot-check inspections of housing units and activity inspection records shall be made prior to completing the endorsement.

CHAPTER 13

NBC WARFARE DEFENSE EQUIPMENT

With the advent of the atom bomb, it is apparent that new tactical weapons are available to both enemy and friendly troops. For every new weapon developed there is a constant search for weapons, or devices to counteract the effect of that weapon.

The only defense against the blast of nuclear weapons, as with conventional weapons, is to be properly protected from the direct force and destructive phases of that particular warhead. However, there is a continuing danger from a nuclear explosion that does not exist after a conventional explosion. This is the harmful radiation that is emitted from a nuclear explosion, known as alpha particles, beta particles, gamma rays, and neutrons.

Because of the great unseen radiation dangers that will be present in the event of nuclear warfare, it will be necessary to use instruments that will make the personnel involved aware of the intensity of the radiation so that all possible precautions can be taken to reduce exposure. Even in peacetime, the danger is forever present for those who work in many of our laboratories and at the various nuclear reactor plants.

NUCLEAR RADIATIONS

Nuclear radiations given off by radioactive elements consist of four types, ALPHA PARTICLES, BETA PARTICLES, GAMMA RAYS, and NEUTRONS.

ALPHA PARTICLES are fast-moving helium ions. In the un-ionized (natural) state, the helium atom has a nucleus made up of two protons and two neutrons; around this nucleus revolve two electrons. When both electrons are stripped from the helium atom in the ionization process, the nucleus then carries two positive charges (two protons). The helium nucleus, with both electrons missing, is the alpha particles. The alpha particles that are emitted from the nucleus in atomic disintegrations are so large, relatively speaking, that they cannot penetrate a sheet of paper.

BETA PARTICLES are streams of fast-moving electrons that have been ejected from the nucleus following the conversion of a neutron into a proton and an electron. The electron becomes the beta particle. Beta particles are high velocity electrons and, since they are only 1/7500 as heavy as alpha particles, they travel several hundred times farther than the alpha particles. But even with this greater speed they cannot penetrate a sheet of aluminum more than a few millimeters in thickness.

GAMMA RAYS, as the name implies, are not particles at all but a form of electromagnetic radiation, very much like light rays or X-rays. Gamma rays move at the speed of light, 186,000 miles per second, and differs from light only in having a much higher frequency; or putting it another way, their wave length is much shorter. Gamma rays have the greatest penetrating power of the three forms of nuclear radiation explained. To reduce the effect of gamma rays following an atomic bomb explosion, it is necessary to use lead shielding several inches thick, or concrete several feet in thickness.

NEUTRON is a fourth type of radiation. As the name implies, it carries no electric charge. Because it is neutral it can enter into the nuclei of atoms of the human body and produce nuclear changes that might lead to artificial radiation. (Of course, this action is not limited to the atoms in the human body.) Destruction of the cell is the usual result, and the person who has been subjected to intense neutron radiation is likely to suffer serious injury, if not death as a result of the exposure. The neutron activity following a nuclear explosion is very short lived and will cease prior to the time when monitoring will normally start.

Table 13-1.—Probable Effects of Acute Nuclear Radiation Over Whole Body (20-KT Bomb; Burst Height, 2,000 Feet)

NOTE: Assume that personnel have had no significant prior exposure

Range from ground zero (yards)	Acute dose (roentgens)*	Probable effects
2,000	50 or less . .	No symptoms of sickness. No decrease in combat effectiveness.
1,750	100	Nausea and vomiting for about 1 day in approximately 2 percent of personnel. No evacuation needed; all able to perform duty.
1,650	150	Nausea and vomiting for about 1 day in approximately 25 percent of personnel. No evacuation expected.
1,550	200	Nausea and vomiting for about 1 day in approximately 50 percent of personnel. Evacuation of about 25 percent by end of 1 week (par. 87). No deaths anticipated.
1,450	300	Nausea and vomiting in all personnel in first day. Evacuation of all as soon as combat conditions permit. About 25 percent deaths, reducible by adequate treatment. Survivors ineffective for full military duty for about 3 months.
1,350	450	Nausea and vomiting in all personnel on first day. Evacuation of all as soon as combat conditions permit. About 50 percent deaths, reducible by medical treatment. Survivors ineffective for full military duty for about 6 months.
1,250	650	Nausea and vomiting in all personnel within 4 hours. Evacuation of all as soon as combat conditions permit Up to 100 percent deaths. Survivors ineffective for full military duty for over 6 months.

*Whole body exposure received in 24 hours or less

UNITS OF RADIATION

Two different quantities are measured by radiac instruments: INTENSITY (or dosage rate) and DOSAGE (total amount of radiation absorbed). Intensity is measured in roentgens per hour (r/hr) or MILLIROENTGENS PER HOUR (mr/hr) and dosage is measured in ROENTGENS or milliroentgens. The roentgen is the amount of X or gamma radiation which produces one electrostatic unit (esu) of charge per cubic centimeter (cc) of air at standard temperature and pressure (STP). This is the unit of exposure dose for X or gamma radiation.

Table 13-1 will give you a general idea of radiation effect measured in roentgens, on the human body.

MEASURING EQUIPMENT

The following portions of this chapter are intended to give you enough background information to familiarize you with the operating and maintenance procedures of the various types of radiac and gas alarm gear. The devices described in this chapter are not necessarily the only devices which you will be required to maintain. Some of these will become obsolete or will be modified to some extent. However, the basic operating and maintenance procedures will be somewhat similar.

You will NOT be held responsible for major repairs or overhauls; however, you will be required to perform appropriate field maintenance. You will probably be given specific

instruction as to what type of maintenance you are to perform on these devices. USE THE APPROPRIATE INSTRUCTION MANUAL FOR ALL RADIAC AND GAS ALARM DEVICES YOU ARE TO MAINTAIN.

The devices with which you will work are designated by a joint electronics type designations system. A set containing an instrument, a carrying case, and other auxiliary equipment will have a number (such as the AN/PDR-18A radiac set). The meter within the set may have a different designation for example the meter IM-75/PDR-18A is a part of the AN/PDR-18A set. The letter after the last number indicates a modified model in the same series (for example, the set is a modified model of AN/PDR-18.)

SURVEY METERS

The AN/PDR-18A radiac set is a portable instrument used to detect and measure high intensity gamma radiation.

The detection of gamma radiation is accomplished by means of a sensitive phosphor element.

DESCRIPTION

The radiac set, AN/PDR-18A (fig. 13-1) consists of a carrying case, the IM-75/PDR-18A radiacmeter, and spare parts for the radiacmeter.

The radiacmeter IM-75/PDR-18A contains a sensitive phosphor, a photomultiplier tube, a switching circuit for the manual selection of intensity ranges, a cathode follower triode, a microammeter, a vibrator type regulated high voltage power supply, and dry cell batteries. The instrument case of the IM-PDR/18 is equipped with a shoulder strap. A handle, located on the battery cover as shown in figure 13-1, provides a hand grip for the operator to use when holding the radiacmeter in a position where the microammeter can be read. A meter range selector switch is located to the right of the handle on the front panel. A push-button for the control of meter dial illumination is located on the handle. A knob for zero setting the microammeter is located in the upper right corner of the front panel, a similar knob is located just above the selector switch on the front panel for the calibration of the microammeter. The meter ranges are 0.5, 5, 50, and 500 roentgens per hour. The meter scales

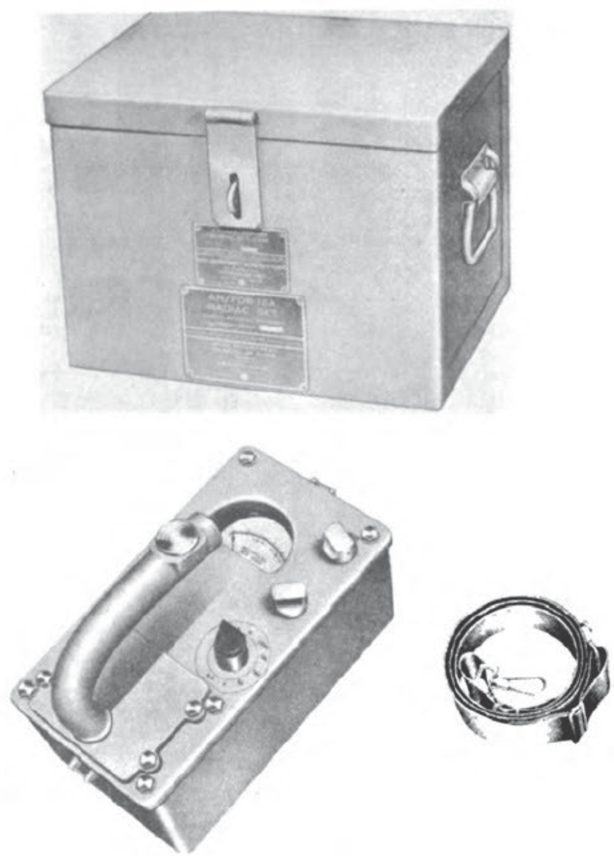


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Figure 13-1.—Radiac set AN/PDR-18.

are mechanically changed by the range selector switch so that only the calibration for the selected range appears on the dial of the microammeter. To indicate the degree of personal danger, each scale has a different background color. The color of the 0.5 scale is yellow; the 5 scale is orange; the 50 scale is pink; and the 500 scale is red.

OPERATING CONTROLS

The operating controls for the IM-75/PDR-18A are shown on figure 13-2.

The RANGE SELECTOR SWITCH is a nine position switch that is mechanically geared to the meter dial. When the range selector switch is in the OFF, A, B, ZERO, or CAL position, a plain white dial marked with ZERO, A, B, AND CAL shows on the meter face. When the range selector switch is in the A position, the

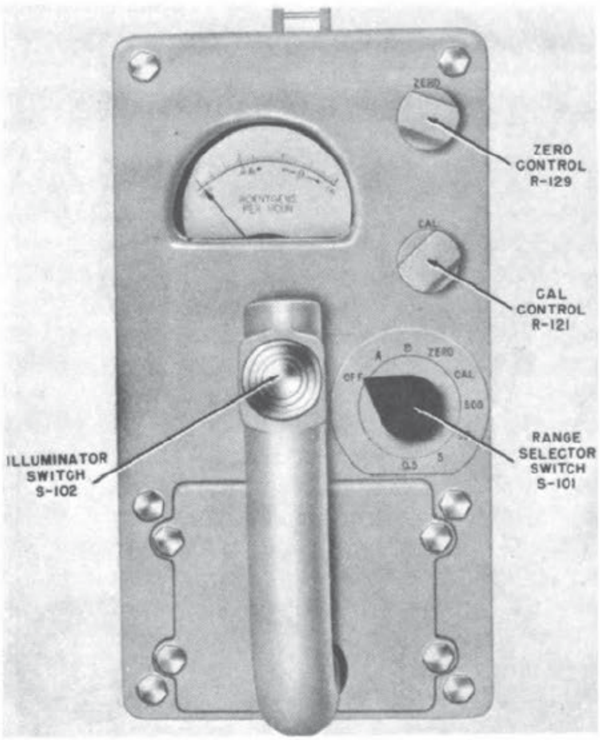

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Figure 13-2.—Radiacmeter IM-75/PDR-18, operating controls.

condition of the filament battery is indicated by the position of the meter needle with respect to the marker A on the meter dial. When the range selector switch is in the B position, the voltage of the batteries supplying the power to the vibrator is indicated by the position of the meter needle with respect to the marker B on the meter dial. When the range selector switch is in the ZERO position, the meter needle may be adjusted to zero with the ZERO control. When the range selector switch is in the CAL position, the radiacmeter may be calibrated by adjusting CAL control for full scale deflection. The remainder of the positions of range selector switch provide different dial scales on microammeter for the different ranges of operation of the radiacmeter.

OPERATION

To place the IM-75/PDR-18A in operation the RANGE SELECTOR switch should be turned from OFF to the A position. The meter needle should be deflected to the right of the marker A on the meter scale. Next, turn range selector switch to the B position. The meter needle should deflect to the right of the B marker on the meter face. Turn range selector switch to the ZERO position and adjust ZERO control for zero deflection on the meter scale. Turn range selector switch to the CAL position and adjust CAL control until full scale deflection is obtained.

CAUTION: When turning the range selector switch to the CAL position, make sure that the switch is fully engaged in the detent provided for that position. Failure to do this may cause inaccurate calibration when CAL control is adjusted for full scale deflection.

Turn range selector switch to the 500 position. The radiacmeter is now ready for measuring radiation. Full scale deflection indicates 500 roentgens-per-hour. If the meter does not show sufficient deflection to read the radiation accurately, shift to the 50 position of range selector switch. If deflection sufficient for an accurate reading is yet not obtained, continue to reduce the setting of the range selector until a satisfactory reading is obtained.

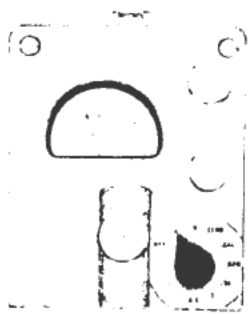
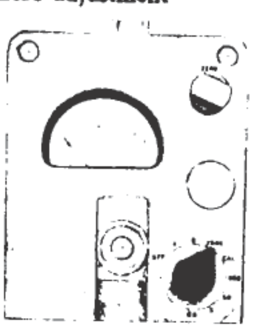
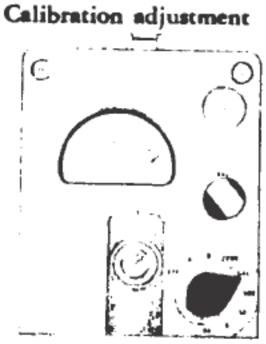
PREVENTIVE MAINTENANCE

The object of preventive maintenance is to anticipate as far as possible the occurrence of troubles and to take steps to prevent them. Preventive maintenance includes periodic cleaning, painting, and inspection.

The front panel assembly and main housing should be checked for cleanliness and scratches. Any scratches in the paint should be retouched with a brush. The screws that secure the front panel to the instrument case and the screws that secure the battery box assembly to the front panel, should be checked to see that they are tight.

NOTE: In all cases where the fungus-proofing film is broken during adjustment of the apparatus, recoat the break with fungus-proofing compound. Specification MIL-V-173, by brush application.

You should never attempt any extensive or complicated repairs since a high degree of technical skill, knowledge, and experience are required. By means of simple tests and procedures, you can perform simple preventive maintenance, and in case of emergencies, effect certain repairs. Routine checks to determine

WHAT TO CHECK	HOW TO CHECK	PRECAUTIONS
Filament Battery Voltage 	Range selector switch S-101 in A position. Read microammeter M-101.	Reading should not be to left of A marker.
Vibrator Power Supply Primary Voltage 	Range selector switch S-101 in B position. Read microammeter M-101.	Reading should not be to left of B marker.
Zero adjustment 	Range selector switch S-101 in ZERO position. Read microammeter M-101, adjust ZERO control R-129.	ZERO reading on microammeter M-101 should be obtained.
Calibration adjustment 	Range selector switch S-101 in CAL position. Read microammeter M-101, adjust CAL control R-121.	Set full scale deflection on microammeter M-101. CAUTION: when turning the range selector switch S-101 to the CAL position, make sure that the switch shaft is fully engaged in the detent provided for that position.

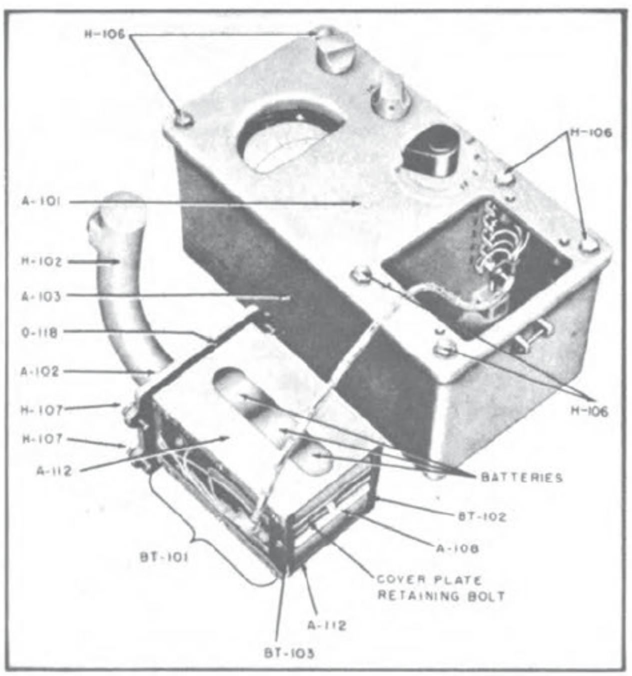
26.141

Figure 13-3.—Routine check chart.

whether the equipment is performing satisfactorily should be made each time the equipment is used. Figure 13-3 shows the checks that should be performed. Any maintenance required as a result of these checks should be limited to the replacement of batteries. Troubles which are not eliminated by the replacement of the batteries should be referred to the proper authority.

Battery Replacement

Figure 13-4 shows radiacmeter IM-75/PDR-18A with the battery box removed (BT-101). To replace the batteries in the radiacmeter, loosen the four battery box cover retaining screws, H-107, which fasten the battery box cover. Remove battery box, BT-101, and place alongside instrument, as shown in figure 13-4. Remove the battery box cover plate, A-108, by removing the cover plate retaining bolt. Remove batteries from the battery box, BT-101, by inserting a finger in the slot in side plate, A-112, and pushing the batteries, one by one, out of the open bottom of the battery box. When replacing with new batteries, JAN type BA-30/U batteries are recommended for replacement purpose. Insert the new batteries in the battery compartment. When inserting the batteries, be careful to observe the specified polarity, which is stamped on the side plates, A-112. Note that the three batteries in the bottom row are installed with their positive terminals on the right side. Before replacing the battery box cover plate, A-108, check the battery voltages as described in figure 13-3. If these voltages do not check correctly, first examine for correct battery polarity inside the battery box, and then try different batteries. If the voltages then fail to appear, the set should be sent to the radiac repair shop.



100.128
Figure 13-4.—Radiacmeter IM-75/PDR-18, Battery box removed.

When reinstalling the battery box, BT-101, in the recess provided in the instrument case cover, A-101, carefully coil the connecting cable in a single vertical loop alongside contact mounting plate BT-103. DO NOT ALLOW THE CONNECTING CABLE TO COIL UP AT THE BOTTOM OF THE RECESS. The cable may be damaged by a possible leak from the batteries if it is allowed to remain in the bottom of the battery recess.

AN/PDR-27CY (DESCRIPTION)

The AN/PDR-27 (any letter designation) is a portable, watertight, battery-operated instrument used for detecting and measuring combined beta and gamma radiations from 0 to 5 milliroentgens per hour, or gamma radiations alone from 0 to 500 milliroentgens per hour.

The radiac set consists of a radiacmeter IM-140/PDR-27CY which is the main unit; it is equipped with a carrying handle, and also may be carried by an externally connected shoulder harness. Radiac Detector DT-53B/PDR-27 is a probe attached externally, by means of a flexible cable, to the radiacmeter. The detector is normally carried in an external well on the radiacmeter and can be easily removed. When measuring gamma radiation, the detector can be used in or out of the well; beta radiation, however, can only be detected when the detector is removed from the well and the beta shield on the probe is moved aside. The radiacmeter also houses the chassis for electronic gear, an indicating meter, and dry batteries. Case CY-963A/PDR-27 is a light-weight carrying case which houses the radiacmeter, radioactive test sample MX-1083B/PDR-27, headset H-43/U, harness ST-119/PDR-27, spare tubes, two wrenches, and two copies of the instruction

book. The complete radiac set AN/PDR-27CY is illustrated in figure 13-5.

The carrying case houses all other radiac set units. It is equipped with carrying handles and hasps, and is so constructed that it can be completely disassembled for decontamination. A spare parts compartment is provided in the case.

The radiacmeter consists of three castings. One casting is made up of the handle which is cast integrally with a plate which serves as a water-tight cover for the battery compartment. The second panel casting provides the means for mounting the electronic chassis, meter, range switch, headset jack, and a compartment for the batteries. The remaining casting completes the waterproof enclosure and provides a well at one end to hold the detector probe. All joints between castings are made watertight by the use of rubber O ring gaskets, and screws to draw the joints tight.

Mounted on the panel are an indicating meter, a range switch, and a headset jack. Illustrated in figure 13-6 is the front panel of the radiacmeter. Mounted on the underside of the panel are the electronic elements of the equipment including a plug-in unit containing three subminiature tubes and their associated circuit elements.

The indicating meter face has a window behind which is placed a meter card with four colored scales. The meter card is carried on a shaft turned by a sprocket gear. Rotation of the card shaft places the scales, one at a time, within the meter face window; only one scale at a time is visible.

The range switch is a three-wafer, five section, switch with six operating positions selected by the switch shaft detents. Mounted on the switch shaft is a sprocket gear, connected by a spring-loaded chain with the gear on the

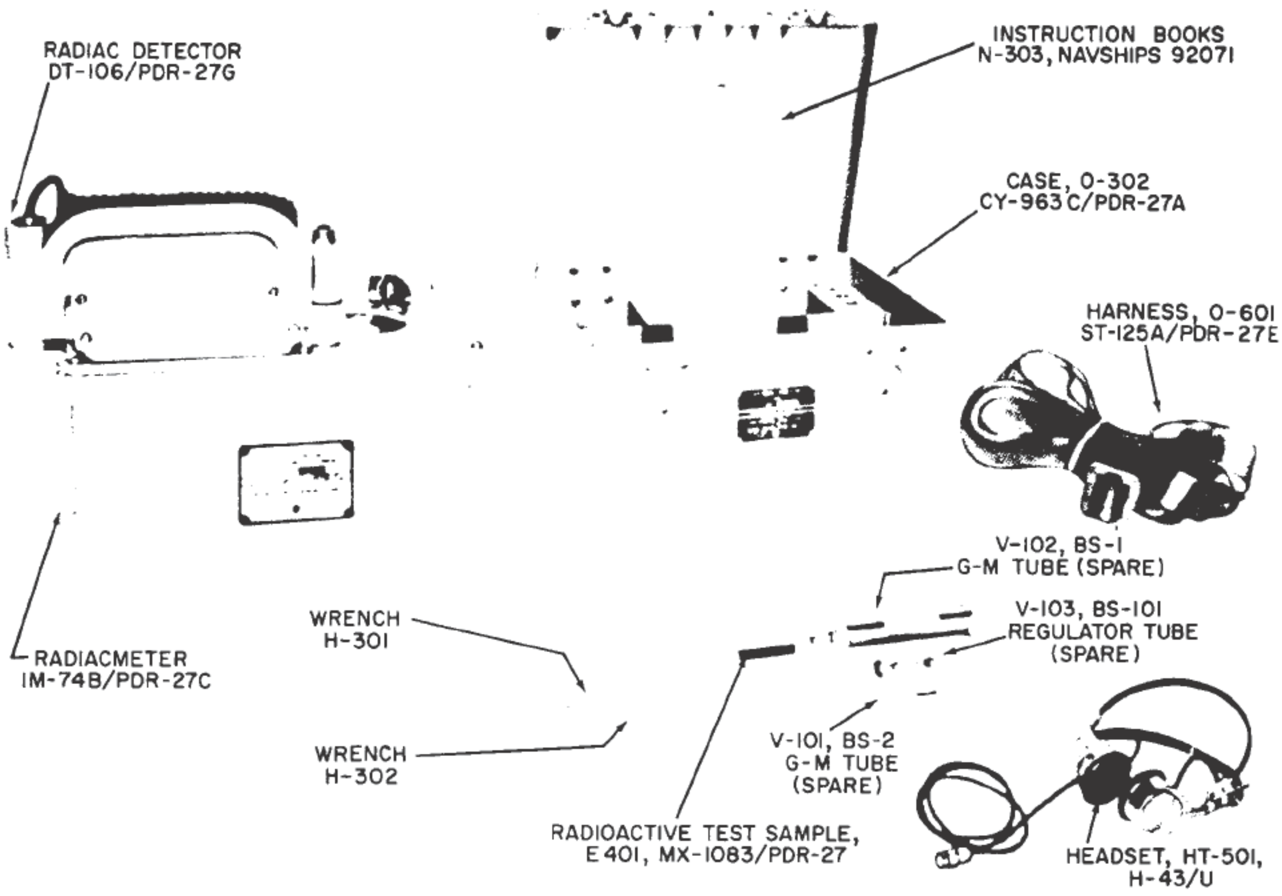


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Figure 13-5.—Radiac set AN/PDR-27 CY.

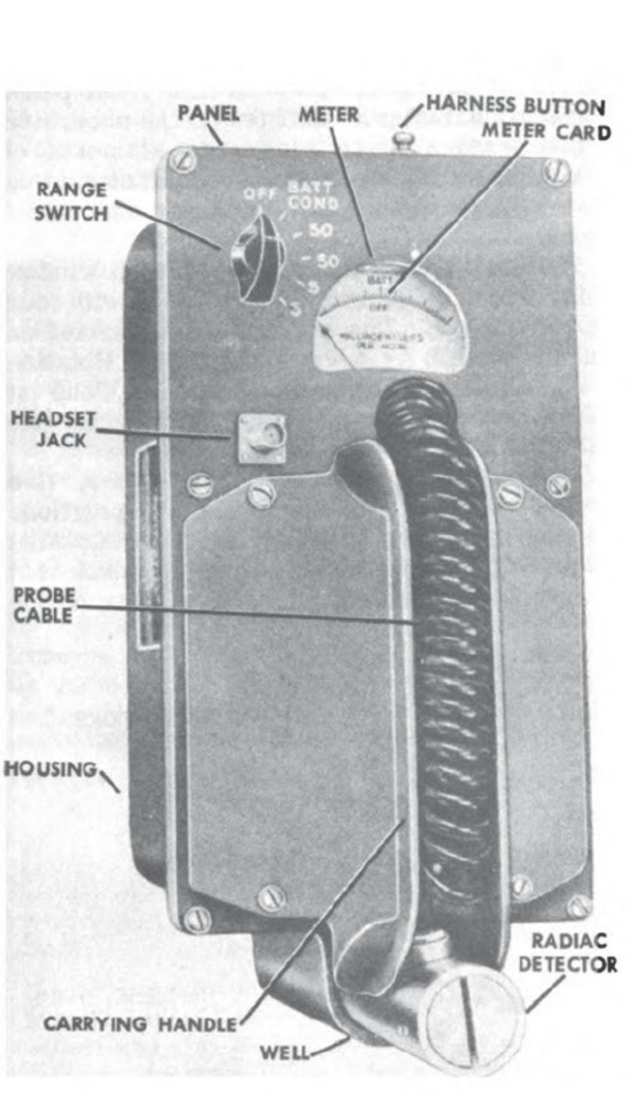

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Figure 13-6.—Radiacmeter, front view.

card shaft. As the range switch is turned to the various operating positions, the card shaft positions the corresponding scales of the meter card in the meter face window.

The battery power is conveyed to the electronic chassis through the wall of the battery compartment by means of a waterproof feed-through terminal strip. Eight single cell D type batteries are enclosed in a compartment within the plastic case located in the watertight battery well housing of the AN/PDR-27CY. This plastic case contains both the batteries and the vibrator power supply. The batteries are located in separate compartmented area in the upper portion of the case, to facilitate easy battery replacement.

The carrying handle is constructed to allow space for the radiac detector flexible cable when the detector is stowed in its well.

The radiac detector is a probe consisting of a Navy type BS-1 G-M tube contained in a cylindrical metal housing. At one end, the housing is closed by a threaded plug; at the other end, a threaded retaining ring bears against the body of the Geiger-Muller (G-M) tube but leaves a mica window exposed. The G-M tube is supported by a rubber gasket at one end. Electrical connection to the tube is made by a kinkproof flexible cable which passes through a waterproof packing gland in the cylindrical housing. A spring-retained metal shield covers the mica window of the G-M tube. When the shield is over the window, beta radiations are prevented from entering the tube; the shield can be swung aside when beta-plus-gamma radiations are to be detected. A metal guard is secured directly over the window.

CAUTION: Since the mica window is only 0.0005-inch thick, it is extremely fragile. Do not touch the window under any circumstances, as damage to the tube will result. Do not rely on the guard to protect the mica window; the guard openings are large enough so that sharp objects can pass through and pierce the window.

The headset provides the operator with aural (sound) indications of radiation intensity when plugged into the jack on the radiacmeter front panel.

The shoulder harness, an adjustable strap made of a nonabsorbent plastic, is used for carrying the radiacmeter and probe during operation. Metal clips on the harness fasten to harness buttons secured to the radiacmeter housing.

The radioactive test sample consists of a plastic tube containing 7 micrograms of radium. The tube is flattened at one end to facilitate handling. The radium provides a radiation source that permits the operator to ascertain the operating condition of the radiac set when no known radiation field is available.

WARNING: Because radium is potentially dangerous, serious skin and internal burns may result if the test sample is held close to the skin for prolonged periods. When using the test sample, handle it only long enough to ascertain the operating condition of the radiac set; then replace it in its storage compartment in the carrying case. If the radio-active test

sample is broken, notify your commanding officer immediately and request disposal instruction.

OPERATION

To operate the radiac equipment remove it from the case, attach the shoulder harness, and plug in the headset. The condition of the battery is then checked by turning the range switch to BATT COND. The meter pointer should rest at the right of the line marked BATT on the meter face. Set the range switch at either 500, 50, 5, or .5, depending on the intensity of the radiation. Check for the presence and the intensity of radiation by observing the meter reading or the frequency of the clicks in the headset. When necessary, illuminate the meter face by tilting the radiacmeter so that the panel is in a 45-degree position, or depress momentary contact switch directly in front of the handle. When the combined beta and gamma radiation from an object is to be measured, turn the range switch to .5 or 5, remove the radiac detector from the well of the radiacmeter, move aside the beta shield on the probe, point the probe at the object to be investigated, and move the probe close enough to the object to obtain a meter indication. For general monitoring, the external probe (DT-106/PDR-27G) is used in conjunction with the 2 lower scales, (.5 and 5 milliroentgens/hr). When using the 2 upper scales (50 and 500 milliroentgens/hr) return the external probe into the well and monitor with the entire instrument.

In order to stop the equipment turn the range selector switch to OFF. To stow the equipment remove the harness and headset from the radiacmeter, replace the radiac detector in the well of the radiacmeter. If the detector does not slide easily into the well, or if the cable does not coil tightly over the handle, rotate the probe so as to add or subtract turns to the coiled cable until the detector can be readily stowed. Unhook the radiacmeter from the shoulder harness, and remove the harness. Stow the radiacmeter, harness and headset in the carrying case.

MAINTENANCE

Check the condition of the batteries by turning the range switch S-101 to BATT COND position. The pointer on the meter should read to the right of the line marked BATT in the center of the meter scale. If the meter reading is low, the batteries are weak, and should be replaced. If batteries have corroded, clean battery compartment thoroughly.

To install batteries remove the radiacmeter from the carrying case and remove the four screws securing the handle and cover of the battery compartment. Remove the cover, then remove the weak or defective batteries. Replace with new batteries, and replace cover. Replace the four screws securing the cover and tighten. The screws must be tightened equally on all sides, or rubber gasket will be damaged.

Preventive maintenance is performed on equipment (usually when the equipment is not in use) to keep it in good working order so that there will be minimum interruptions in service. The routine maintenance which you are to perform is given in table 13-2.

DOSIMETER

The IM-9F/PD (fig. 13-7A) is a pocket radiacmeter which is of the instant reading type, having a scale of 0 - 200 milliroentgens (mr). The instrument measures and indicates the accumulated dose of X and gamma radiation to which the wearer has been exposed. At one end of the radiacmeter is an optical eyepiece and at the other end is the charging contact. A scale calibrated in mr is mounted in such a manner that the amount of radiation to which the wearer has been exposed can be read directly by holding the radiacmeter up to a source of light and looking into the eyepiece.

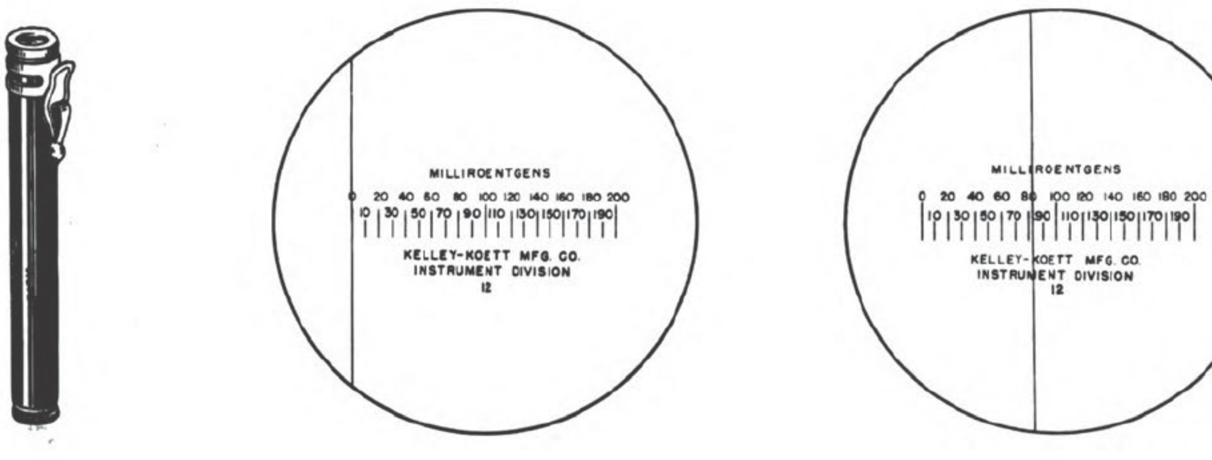
Part B of figure 13-7 shows the meter indicator at zero, which indicates it is sufficiently charged.

Part C of the above figure shows the scale reading after the instrument has been exposed to 83 mr of gamma radiation.

A radiac-detector such as the detector charger PP-354C/PD is required to keep it charged.

The IM-107/PD and IM-143/PD pocket dosimeters are identical in appearance and similar to the IM-9F/PD (fig. 13-8). All three dosimeters must be charged with either the radiac detector charger PP-311A/PD or PP-354C/PD (figs. 13-9A and B). One charger can be used to set many self reading dosimeters.

The range of the IM-107/PD is 0-200 roentgens while the range of the IM-143/PD is 0-600 roentgens.



A B C

A. Pocket radiacmeter IM9F/PD(A)
B. Charged radiacmeter
C. Radiacmeter scale reads 83 mr

26.143

26.143

Figure 13-7.—Pocket radiacmeter IM9F/PD(A) and scale indications for two conditions of charge.

MAINTENANCE

Since pocket types of radiacmeters are hermetically sealed, no corrective maintenance can be performed in the field. These instruments are very delicate and are sensitive to dust and moisture as well as rough handling (shock). Dust and moisture in the charging end of the chamber will make charging difficult. This can be corrected by using a mild stream of dry air directed on the end of the chamber to remove dust particles and moisture collection.

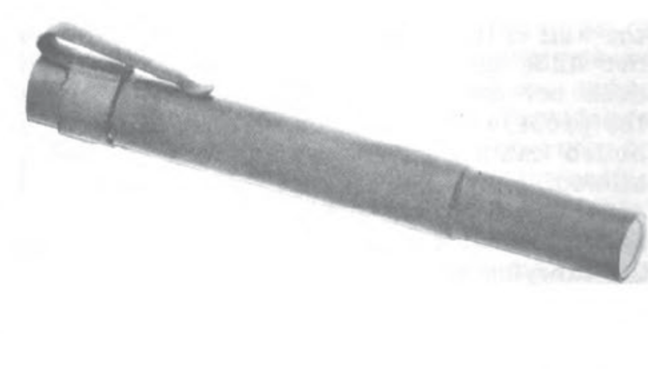
Cleaning and decontamination can be performed by removing the clip and washing both the barrel and clip with soap and water.

To field check the instruments, charge to zero on the scale in a space free from radioactivity. Observe leakage on the scale for a period of 4 to 8 hours. Heading should be very near zero. If it is not, consider the unit defective and return to the nearest radiac repair facility for further testing, and possible replacement.

In stowing the instruments, they should be wrapped tightly in a plastic bag, "Saran Wrap", or similar material and stowed in a dust free area.

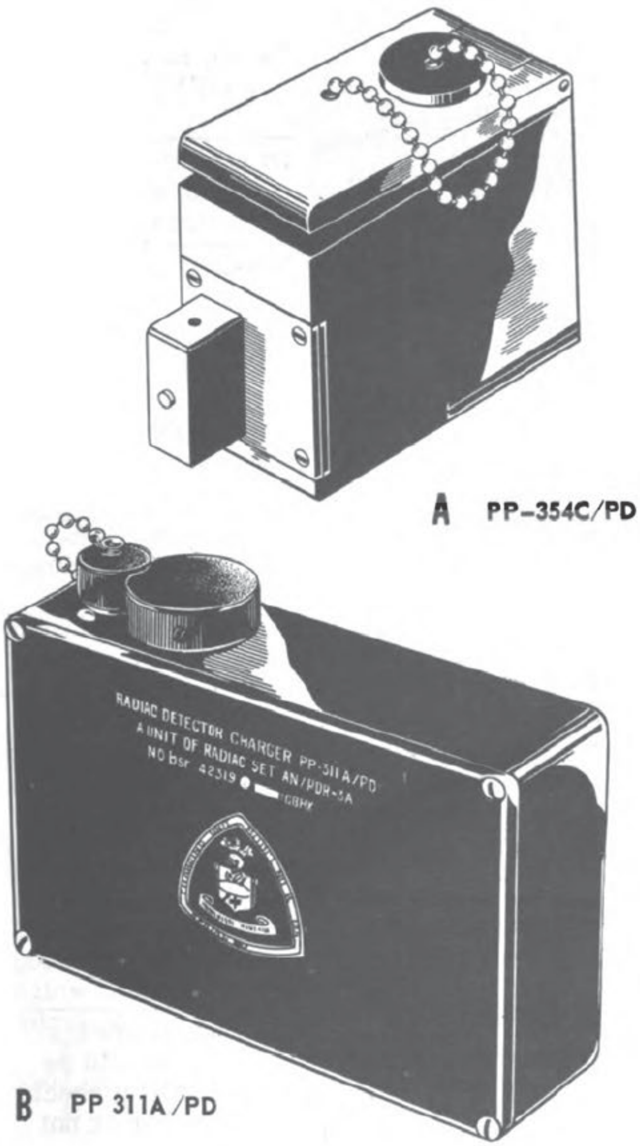
DT-60/PD RADIAC DOSIMETER

The DT-60/PD radiac dosimeter (fig. 13-10) is a non-self-indicating personnel dosimeter



26.144

Figure 13-8.—IM-107/PD radiacmeter.



11.360.1

Figure 13-9.—Radiac detector chargers.
A. Radiac detector charger PP354C/PD
B. Radiac detector charger PP311A/PD

which is worn about the neck as a pendant. The instrument detects the accumulated doses of X or gamma radiation from 0 to 600 roentgens. It requires an associated radiac computer-indicator CP-95/PD for reading.

No corrective maintenance can be performed. Replace damaged or defective radiac-detectors. Clean and decontaminate by washing the entire assembly with soap and warm water.

COMPUTER INDICATOR

The CP-95/PD computer indicator (fig. 13-11) is a portable piece of equipment designed for computing and indicating the total amount of X and gamma radiation to which the DT-60/PD radiac detector has been exposed. It operates from a 120-volt, 60 cycle, a-c power source.

The entire equipment consists of one unit. A cover assembly (fig. 13-12A), held by four latch fasteners, encloses the front panel. You will notice that the panel (fig. 13-12B) contains a roentgens-indicating meter with two scales, 0 to 200 roentgens (black) and 0 to 600 roentgens (green), a red indicating lamp, and two meter illuminating lamps (not visible). In addition, a range toggle switch (for changing meter ranges), a power switch, two potentiometer controls, a power cable receptacle, and three fuses, one of which is a spare. The lower portion of the front panel contains a horizontal opening with a spring-loaded door through which a pivoted sector and skillet assembly can be rotated. The sector and skillet assembly contains three recesses: one remains empty, one contains a calibration standard, and the third is for the insertion of the radiac detector DT-60/PD which is to be read. The assembly can be returned by means of an attached telescopic sector handle (test lever), into the housing of computer-indicator to locate any one of these recesses under an ultraviolet light. A rubber stop is provided to prevent rotation of the calibration standard outside the case during operation. The top of the case contains a nameplate, instruction plate, carrying handle, and two protruding pins for opening the DT-60/PD radiac detector.

The front cover assembly (fig. 13-12A) contains three additional fuses, two Allen wrenches for use in the disassembly of the equipment, two small pin wrenches for opening the DT-60/PD detector, a large spanner wrench, and the power cable assembly.

OPERATION

One CP-95/PD can be used to read many DT-60/PDs.

To operate the computer-indicator it must first be connected to a 120-volt a-c source of power. Then proceed to operate the equipment in the following manner:

1. Rotate the sector handle (test lever) (refer to figure 13-12B for location of parts) outward and extend the lever until it catches in its detent.

Table 13-2.—Routine Maintenance Check Chart

What to Check	When to Check	How to Check	Precautions
1. Battery condition.	Weekly	Turn range switch to BATT. COND. Meter pointer should rest at the right of red line marked BATT.	Return range switch to OFF.
	Monthly	Open BATT. compartment and make a visual check for leakage.	Do not get acid on hands, clothing or electronic parts.
2. Exterior surfaces of radiacmeter, radiac detector, and shoulder harness.	Weekly	Wipe with a clean, dry cloth, removing all dirt and dust.	None.
3. Radiacmeter front panel screws.	Weekly	Tighten with screw driver.	Do not tighten excessively.
4. Range switch knob.	Weekly	Rotate knob. If loose, tighten setscrew with screw driver. Check to see that knob rests snugly against gasket. If it does not, loosen setscrew, push knob tightly against gasket and re-tighten setscrew.	Do not tighten setscrew excessively.
5. Radiac detector plug.	Weekly	Remove all dirt from plug. Obtain special wrench symbol H-301 from carrying case. Insert rounded end of wrench into plug slot, and tighten.	Do not tighten excessively.
6. Packing nut at both ends of radiac detector cable.	Weekly	Tighten with open end wrench.	Do not tighten excessively.
7. Radiacmeter circuit	Monthly	Check radiacmeter with radioactive test sample. (See Section 3, par. 3.)	The radioactive test sample should be used only to check on whether or not the radiacmeter is operating. It should not be used as an accurate means of calibrating or checking sensitivity of this unit. If reading decreases vertically, investigate and correct cause.
8. Headset	Monthly	Remove dirt. Check tightness of screws and connections.	None.

3.177

Figure 13-10.—Radiac detector DT60/PD.

2. Rotate the POWER switch S101 in its START position until the red indicator lamp, I103 located in the meter face, lights; then release the switch. It will return to its ON position and the red indicator lamp will go out. Allow the equipment to warm up for 3 to 5 minutes.

3. Place the meter-range toggle switch, S102, in its 200 R(roentgens) position.

4. Place the test lever to its CHANGE DT-60 position.

5. Remove the cover of the DT-60/PD by using the wrenches provided in the front panel cover assembly or the two pins located on top of the equipment near the carrying handle. The DT-60/PD can be held in the hand and the small pin wrench used to unscrew the cover. Should the cover be too tight to open with the pin wrench, then use the large spanner wrench mentioned earlier (the large spanner acts as a vise, keeps the base of the DT-60/PD from rotating) to hold the radiac detector, while you unscrew the cover with the wrenches provided or two pins located on the top of the equipment mentioned above.

NOTE: Be sure the DT-60/PD's are free of dirt or dust before reading. Be sure to avoid touching the enclosed glass once the cover is removed from the radiac detector DT-60/PD. Dirty or greasy fingertips are fluorescent and will give erroneous radiation indications.

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Figure 13-11.—Radiac, computer-indicator CP-95/PD.

Soap and water may be used to clean the glass portion and the case of the radiac detector.

6. Insert the base (which contains the enclosed glass) of the dosimeter into its position, marked DT-60, in the sector and skillet assembly. Be sure it is seated on the locating pins.

7. Rotate the sector handle until it detents in its CAL A position.

8. Adjust the A ADJ control R138 until the black meter needle coincides with the A position on the meter scale.

9. Rotate the sector handle to its CAL STD position.

10. Adjust the CAL ADJ control R124 until the black meter needle coincides with the fixed red meter pointer.

11. Repeat the adjustments until the black meter needle coincides with both the A position and the fixed red pointer, when the sector handle is CAL A and CAL STD positions, respectively.

12. Rotate the sector handle to its READ position (extreme counterclockwise) and read the roentgens as indicated by the black meter needle. (Do not attempt to repeat readings for greater accuracy, unless readings are being made for special purposes.)

13. Should the meter indicate a reading above 200, throw the range switch, S102 to its 600 R. position and read.

14. For further readings, begin with number 3.

MAINTENANCE

There is very little maintenance that you can do. The operating procedures (through 14) are an integral part of the routine check. The only thing you can do is to follow the above mentioned operating procedures to make certain that each reading obtained is correct.

NOTE: You shall not perform any emergency maintenance procedures without proper authorization. This equipment employs voltages which are dangerous and may be fatal if contacted by personnel. Extreme caution must be exercised when anyone is working with this equipment.

DOSIMETER CHARGER

The radiac detector charger PP-354C/PD (fig. 13-9A) is used to charge radiacmeters (dosimeters) IM-9F/PD and or similar types. This charger is an electrostatic type generator capable of generating 0 to over 180-volts, d-c by slowly turning the charging knob in a clockwise direction to bring hairline in the dosimeter to zero.

The charger PP-354C/PD is contained in a watertight metal case measuring 2 7/16 inches long by 1 inch wide by 2 inches high, overall. The hinged top section of the case contains the upper part of the charging socket, which continues into the body of the case. A removable plug closes the charging socket when it is not in use and the plug is secured to the charger by a length of bead chain. The bar-type operating knob for the charger is mounted on one end of the case. A window is provided in the bottom of the case to transmit light to the user of the radiacmeter.

OPERATION

The operation procedures for the radiac detector charger are given and illustrated in figure 13-13.

MAINTENANCE

The radiac detector charger PP-354C/PD cannot be repaired because it cannot feasibly be disassembled. Therefore a faulty charger should be removed from use and turned into the nearest repair facility.

The exterior surfaces of the charger can be cleaned with a clean lintless cloth. Rub gently over all surfaces. Do not use any solvent, especially alcohol, on the EXTERIOR surfaces.

Particles of dust or lint in the charging socket can usually be removed with a stream of clean dry air. Exceptionally stubborn particles may have to be flushed out carefully with pure water-free ethyl alcohol. Use the least amount of alcohol possible, then evaporate it with blasts of clean dry air.

CAUTION: Do not blow the breath into the charging socket to clean it. Permanent impairment of socket insulation may result.

Moisture resulting from condensation can be removed by heating the charger with a 60-watt bulb. Place the bulb about 6 inches away from the charging socket opening and leave it there for about 15 minutes.

NOTE: After cleaning the charger by any of the methods described above, it must be checked by charging two or more radiacmeters several times. Any evidence of imperfect opera-

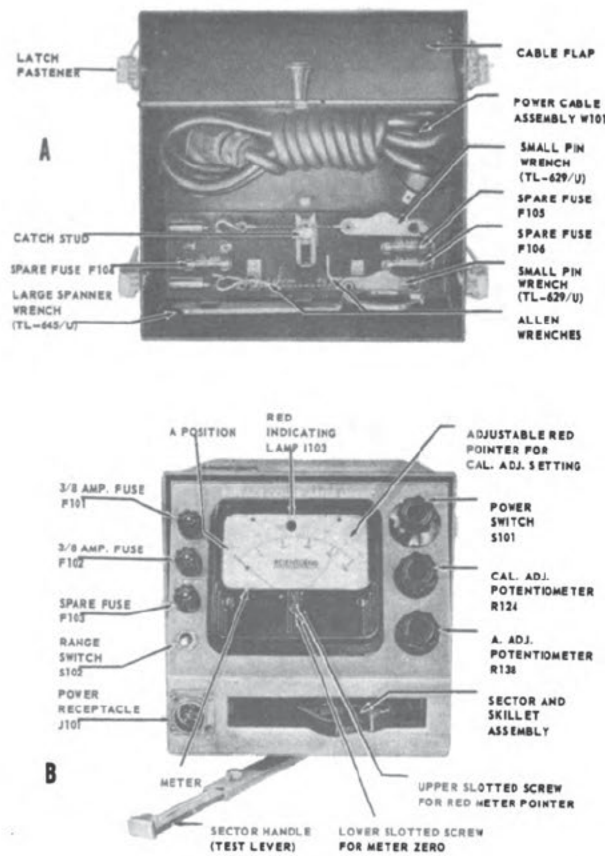

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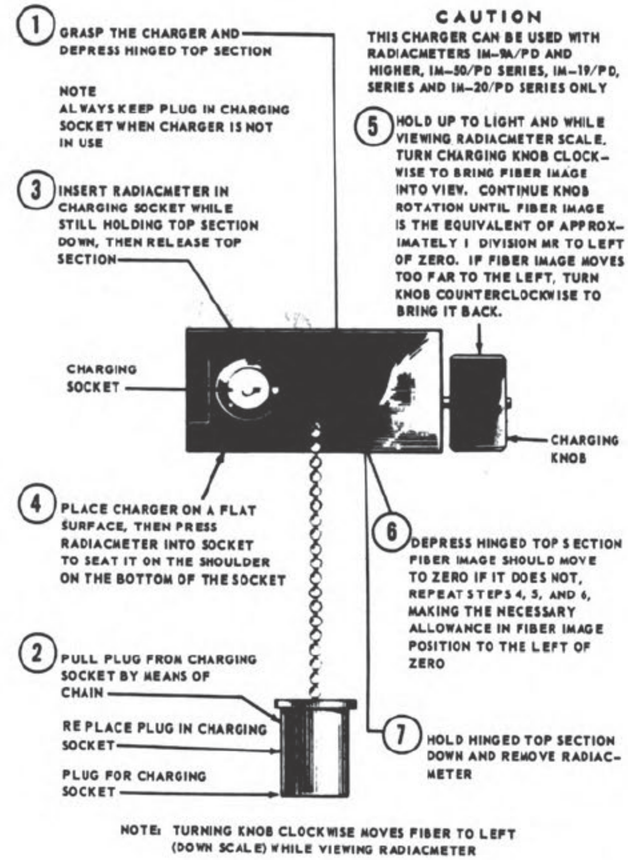
Figure 13-12.—Radiac computer-indicator CP-95/PD.



26.145
Figure 13-13.—Radiac detector charger PP-354-C/PD and operating instructions.

tion, such as leakage or difficulty in charging, should warrant removing the charger from use.

CAUTION: Maintenance personnel must always be cognizant of the fact that radiac equipment is used for the primary purpose of protecting human life and health, and for that reason they should not permit the use of faulty radiac equipment.

AIR SAMPLER

The air particle sampler, HD-251/UD (fig. 13-14) is intended for use in any closed space where airborne microscopic radioactive particles are likely to be present. By measuring a sample volume of air, a direct evaluation of the concentration of radioactive material may be read on AN/PDR-27 series radiac sets, or counted with a suitable G-M tube and scaler.

The air sampler consists of the air moving turbine, metering unit, power cord, filter papers, two filter holders, and a meter cap.

OPERATION

To use the air particle sampler, open the top of the air mover case and remove the power supply cord, filter holder, and filter. Fit the filter into the holder and plug the holder into the inlet opening. Be sure the air meter is set at zero. You then place an AN/PDR-27 series radiac set in a location that is practically free of any radioactivity, at any rate in a location that has a reading of less than 0.1 mr/hr.

Place the power cord plug into a 110-volt, 60 cycle, a-c power source; and make sure the air sampler switch is in the OFF position. Now turn the switch to the ON position and take

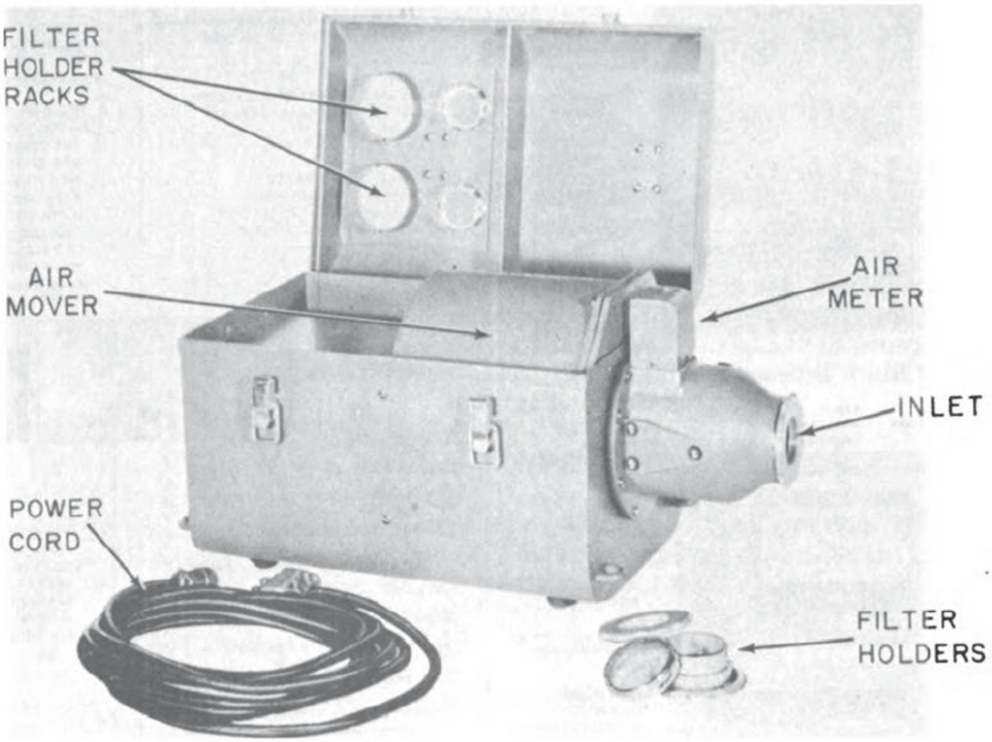


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Figure 13-14.—HD 251/UD equipment.

a sample of 20 cubic meters of air as indicated by the flow totalizer.

WARNING: Once the unit is turned ON, DO NOT turn it off until the air mover motor is up to full speed.

After collecting the sample of the air, turn the switch to the OFF position and remove the plug of the cord from the power source. DO NOT REMOVE THE PLUG WHILE THE SWITCH IS IN THE "ON" POSITION. Remove the filter holder with the filter in place, and carry it to the AN/PDR-27 to measure the amount of radioactivity picked up by the filter.

MAINTENANCE

The air particle sampler, HD-251/UD, is a sealed unit, requiring no repair on the major units. In the event of failure within the air mover unit, the sampler should be returned to the manufacturer for servicing. About the only thing you can do is to check the power cord for worn or frayed insulation, broken or cracked terminals or connectors. If any above mentioned conditions exist, replace the cord.

GAS ALARM (M6A1)

The M6A1 Automatic Field Alarm (gas) (fig. 13-15) is a completely self-contained device for detecting the presence of G-agents in the air. It is housed in an aluminum case with removable front and rear covers, each of which is held in place by six snap catches. The case is equipped with a rigid carrying handle attached to the top. The entire unit is finished in olive drab lusterless enamel.

OPERATION

To operate the gas alarm it must be placed on level ground or a level platform during operation, standing on supporting channels welded to the bottom of the case. If the alarm is not level, the gravity feed of chemical solution to the liquid pump will be affected. After the alarm is leveled remove the cap on the power input connector and insert the plug

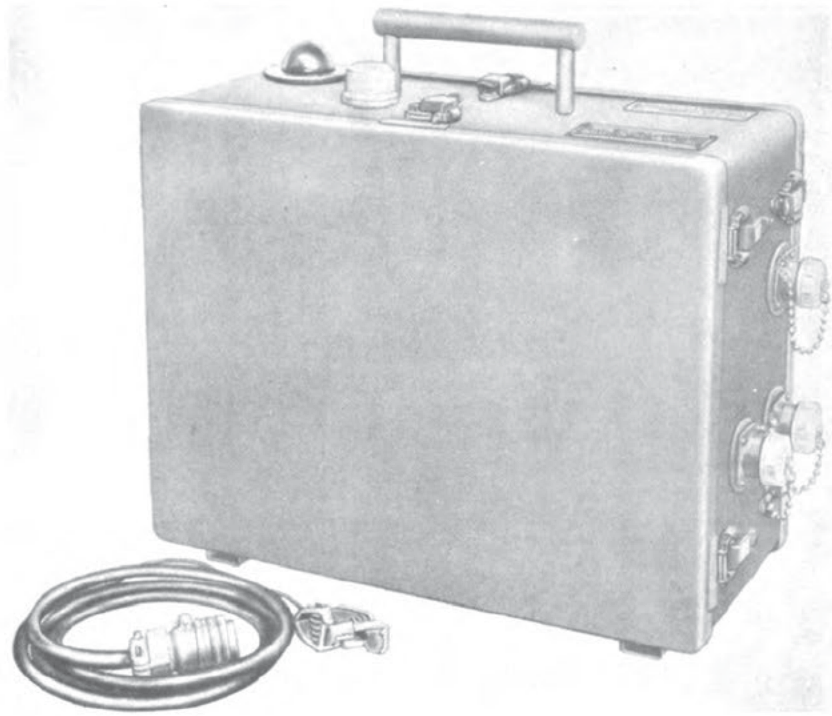

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Figure 13-15.—Automatic field gas alarm M6A1.

of the power cable. Refer to figure 13-16 for following procedures:

1. Screw the threaded shell of the cable plug down on the power connector bushing to hold the plug firmly in place.

2. Connect the battery clips on the end of the power cable to the power source. The power source may be either storage batteries (4, each 6 volts or 2, each 12 volts), a generator, or a transformer-rectifier. (The transformer-rectifier, figure 13-17, is a portable power supply unit for the M6A1 Automatic Field Alarm designed to provide 25 volts (direct current) from any 115-volt, 60 cycle alternating current source. The transformer-rectifier is equipped with two power cables, one is to be used to connect the alternating power source to the rectifier, the other connects the rectifier to the gas alarm.) OBSERVE THE POLARITY INDICATED ON THE CLIPS. Failure to observe this precaution will result in stripping the gears of the timing motor.

3. Note the arrows on the cam knob. If the cam knob rotation is not in the direction indicated (counterclockwise), the clips must be reversed.

4. A transformer-rectifier unit may be supplied with the alarm. If so, the power cable with battery clips, supplied with the alarm will not be used.

5. Shortly after the field alarm is connected to its power source, and while the tubes are warming up, the bridge circuit of the alarm may momentarily become unbalanced, causing an alarm to be given. This condition occurs when the meter indicator moves beyond the second division line to the left of "0". To stop the alarm, simply push the reset switch down and observe the meter. If after a few seconds the meter indicator has not returned to "0" adjust the light source holder by rotating it until the meter indicator reads "0". This adjustment should be made only when dry paper tape is being observed by the phototubes. To test the operation of the alarm, a simulant spot is provided with the reagent kit (fig. 13-18). The simulant spot is used by inserting it over the paper tape into the slot of the head assembly while manually pushing the solenoid fork down.

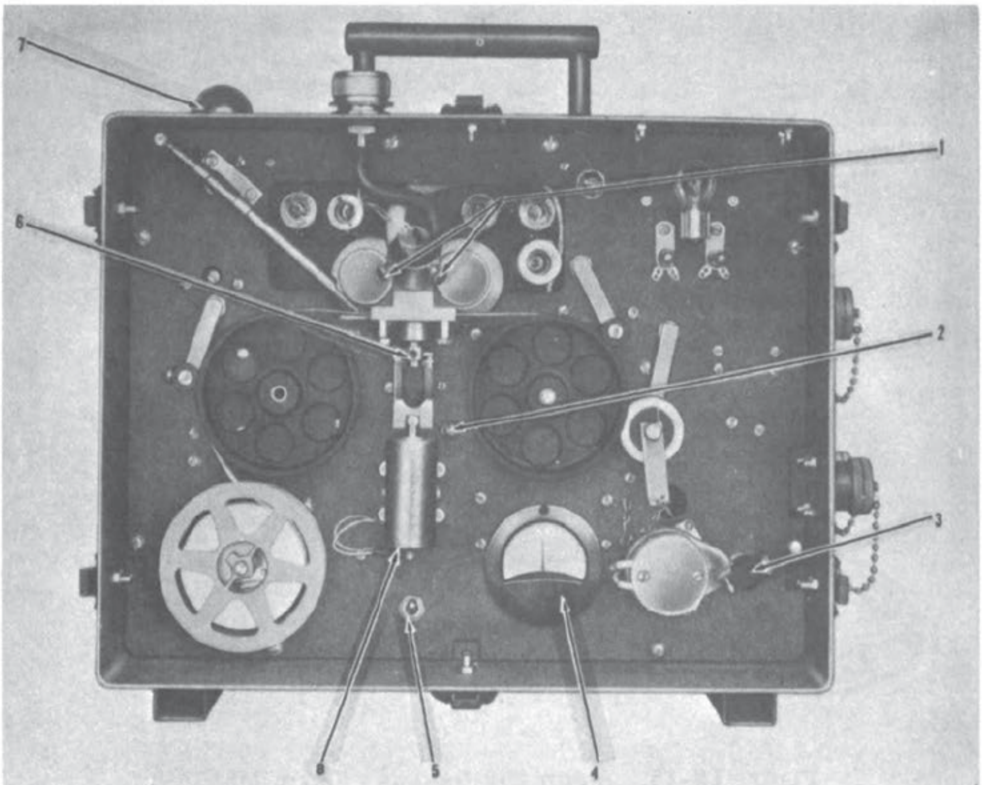

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Figure 13-16.—Gas Alarm Controls and Instruments.
1. Light source adjustment screws
2. Wetting time adjustment screw
3. Cam knob
4. Meter M101
5. Reset switch S101
6. Solenoid adjustment collar
7. Warning lamp
8. Solenoid L101

The insertion of the simulant spot must always be made from the left-hand side resulting first in a meter deflection to the right, and then to the left. When pushed in as far as it will go, the alarm should sound. To stop the alarm, withdraw the simulant spot and momentarily push the reset switch down.

Once the gas alarm is set up and ready to operate it goes through the following cycle: At 5 minute intervals, when no G-agents are present in the air, a small quantity of liquid flows from the feeder extension tube onto the section of tape immediately to the left of the head assembly. Approximately 10 to 15 seconds later, the solenoid below the head assembly operates and draws the platen downward, and about 1 second later, the wet section of the tape advances to position in the head assembly. The solenoid is then released and the instrument resumes operation. When the instrument detects G-agents, the meter indicates current flow in excess of 0.10 milliampere to the left of the center mark on the scale, the warning lamp lights, and the buzzer sounds. Cam knob rotation and paper movement ceases. The air pump in the rear of the unit also stops.

Once the alarm circuit is energized, the alarm continues even after G-agents are no

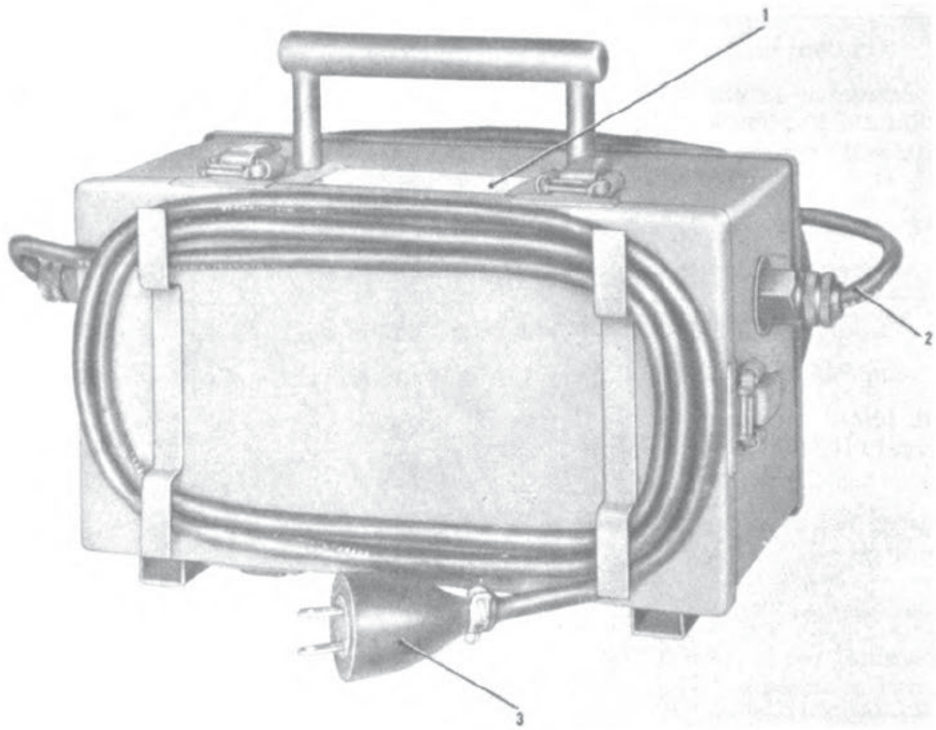

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Figure 13-17.—Transformer-Rectifier Unit.
1. Identification Plate
2. Alarm Connecting Cable
3. A. C. Power Cable

longer present in the air. The detection circuit must then be reset. This is done as follows:

1. Manually push the plunger of the solenoid down to release pressure from the tape.

2. Rotate the right hand tape drum clockwise. This will advance the tape quickly. Rotate the cam knob slowly COUNTERCLOCKWISE to wet the new section of the tape.

3. After the tape is in place, push the reset switch down, hold it for about 3 seconds and release it. The alarm will stop and the unit will resume normal operation.

To stop the instrument, disconnect the power cable from the battery, or, if the transformer-rectifier unit is used disconnect the a-c power cable line plug.

MAINTENANCE

In maintaining the M6A1 gas alarm it is imperative that preventive maintenance services be performed regularly to keep the alarm in proper working order and to lessen the possibilities of mechanical failure (Table 13-3).

General maintenance of the M6A1 gas alarm normally involves the replacement of direct-current amplifier and voltage regulator tubes; light source; warning lamps; phototubes; liquid pump; air pump; and timer motor. It also involves cleaning the platen, liquid line, and air pump valves. One other maintenance function you will probably perform is lubrication. Illustrated in figure 13-19 are the various points to be lubricated and the type of lubricant required.

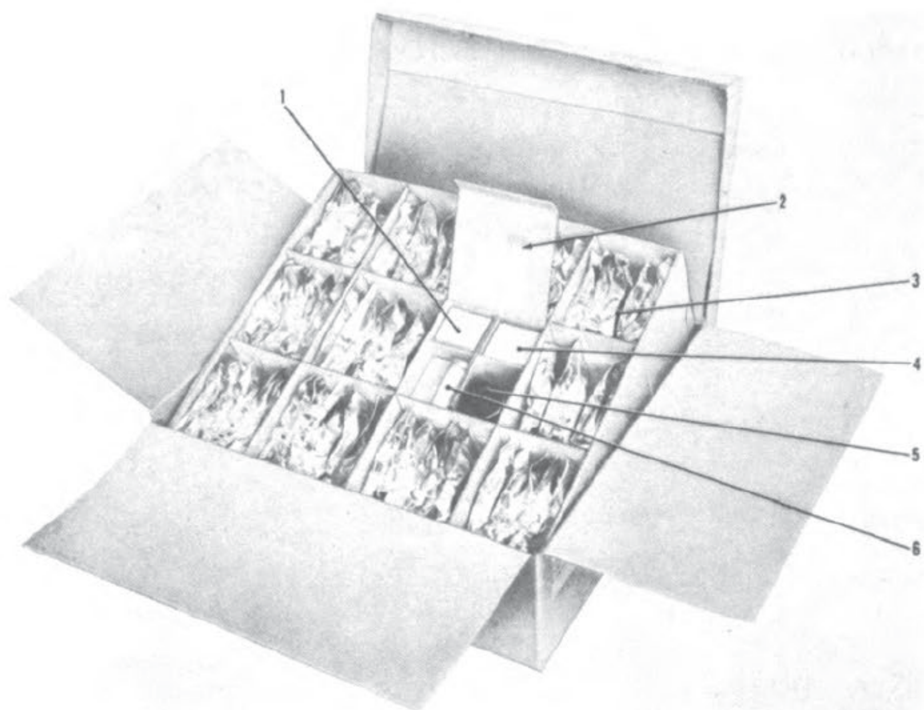

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Figure 13-18.—Gas-agent alarm, reagent kit.
1. Aluminum foil packets
2. Simulant spot
3. Paper reels
4. Clear plastic packets
5. Mixing bottle
6. Filter disks

CAUTION: One point you are definitely NOT to lubricate is the air pump valves. Lubrication will cause sticking and fluctuations in the air pressure.

Table 13-3.—Troubleshooting Chart for the M6A1 Gas Alarm

Trouble	Probable Cause	Remedy
1. Timer Motor Does Not Run	a. Defective resistor R101	Replace resistor.
	b. Defective timing motor	Replace timing motor.
	c. Failure of power source	Examine power cable for breaks or deterioration and replace if necessary. Check battery and replace if necessary. If the transformer-rectifier unit is being used.

Table 13-3. —Troubleshooting Chart for the M6A1 Gas Alarm (Continued)

Trouble	Probable Cause	Remedy
2. Air Pump Motor Does Not Operate	a. Defective air pump motor	Replace motor.
	b. Pump mechanism jammed	Examine pump mechanism for source of jamming, including bearings. Replace defective parts.
	c. Failure of power source	Check power source.
	d. Loose shaft	Tighten set screw securing shaft.
3. Liquid Does Not Wet Tape	a. Liquid tank empty	Refill tank.
	b. Air lock in liquid line	Bleed liquid lines.
	c. Liquid lines clogged	Dismantle liquid lines, soak in water until clear, and reassemble.
	d. Pump spring does not pull piston fully forward	Lubricate piston after cleaning. Replace O-ring if necessary.
4. Tape Does Not Advance	a. Broken pawl spring	Replace spring.
	b. Advance mechanism jammed	Inspect for jammed plunger. Lubricate if required, or replace defective part.
	c. Solenoid plunger fails to pull down	Check solenoid and replace if necessary.
	d. Paper slips on paper advancing reels	Tighten tension roller.
	e. Ladder chain too tight	Loosen idler sprocket.
	f. Microswitch operating solenoid misadjusted	Readjust microswitch actuator.
	g. Plunger return spring too loose	Shorten spring or replace.
	h. Tape does not wind properly on bobbin	Adjust tension of spring, holding bobbin against tape drum.
5. Liquid Does Not Flow	a. Timer motor does not run	See paragraph 1 above.
	b. Broken plunger return spring	Replace spring.
6. Timer Motor and Air Pump Motor Do Not Run; Tubes and Lamp Do Not Light	a. Defective contact on relay K101	Replace relay K101.
	b. Failure of power source	Check power source.

Table 13-3. —Troubleshooting Chart for the M6A1 Gas Alarm (Continued)

Trouble	Probable Cause	Remedy
7. Tape Breaks During Advancement	a. Solenoid L101 does not pull plate away from tape due to:	
	(1) Improper timing of microswitch S103	Correct timing.
	(2) Defective solenoid L101	(a) Check to see that solenoid Plunger and platen spring are clean and moving freely; clean if necessary. (b) Replace solenoid.
	(3) Defective microswitch S103	Replace switch.
	(4) Collar or pull down mechanism adjusted too high	Readjust collar. Travel before plunger hits bottom should not exceed 1/16 inch.
	b. Ladder chain broken or disengaged from sprocket	Repair chain and replace on sprocket.
	c. Too much tension on tape reel	Readjust collar on square shaft to relieve tension.
8. Air Is Not Drawn Through Tape	a. Air filter clogged	Replace filter disk.
	b. Dirt or lint in platen opening	Remove platen, clean and replace.
	c. Leak in air line	Inspect air line tubing for cuts. Replace defective section.
	d. Defective air pump valve	Remove valves and clean out dust and grit. Replace valve balls if necessary.
	e. Loose glass disk below exciter lamp	Recement glass disk in place. Care must be taken to keep glass clean where in line with holes.
	f. Leak around phototubes	Remove head and inspect O-rings on phototubes. Apply a light film of stop cock grease to O-rings or replace if found deteriorated. After slipping O-rings over glass part of tube to shoulder, wipe the glass clean before replacing head.
	g. Leak in head assembly due to defective O-ring seal or damaged phototube base	Remove the two rubber tubes from the top of the head. Remove the moistener plate. Connect one end of a piece of 3/16 inch ID rubber tubing to the air pump and the other end to one of the inlets from which the air intake tubes were removed.

Table 13-3. —Troubleshooting Chart for the M6A1 Gas Alarm (Continued)

Trouble	Probable Cause	Remedy
	g. Leak in head assembly due to defective O-ring seal or damaged phototube base	With the air pump operating, place your thumb over the opening, on the bottom of the head, which corresponds with the side to which the air hose is connected. If this side does not leak, a suction on the finger will be noticed and the air pump will labor. Repeat the same test on the other air inlet. If no suction is noticed on one side only, the leak should be found in a defective O-ring seal or a damaged phototube base.
9. Detector Circuit Does Not Operate	a. Burned out or darkened illumination lamp	Replace lamp.
	b. Illumination lamp incorrectly positioned	Adjust illumination lamp.
	c. Burned out regulator tube V207	Replace tube.
	d. Defective relay K102	Replace relay.
	e. Defective meter M101	Replace meter.
	f. Defective phototube V203, or direct current amplifier tube V201 or V204	Replace each tube in turn to localize trouble.
	g. Defective resistor	Perform voltage measurements to localize trouble. Replace any defective components.
10. Alarm Circuit Does Not Operate After Timer Motor Is Replaced	Timer motor leads reversed	Reverse motor leads.
11. Alarm Operates With No G-Agents Present	a. Defective phototube V206 or direct current amplifier tubes V202 or V205	Replace tubes V206, V202, and V205 in turn, to localize the trouble.
	b. Defective resistor, producing unbalanced circuit condition	Perform voltage measurements to determine location of defective part, and replace the part.

Note: Interference from Other Gases

a. The presence of gases such as chlorine, nitrogen dioxide, cyanogen chloride, and other strong oxidizing agents may discolor the wetted portion of the tape and thus give an alarm.

b. The presence of hydrogen cyanide gas may inhibit the formation of a color spot by G-agent and thus cause the alarm to lose sensitivity or become completely unresponsive.

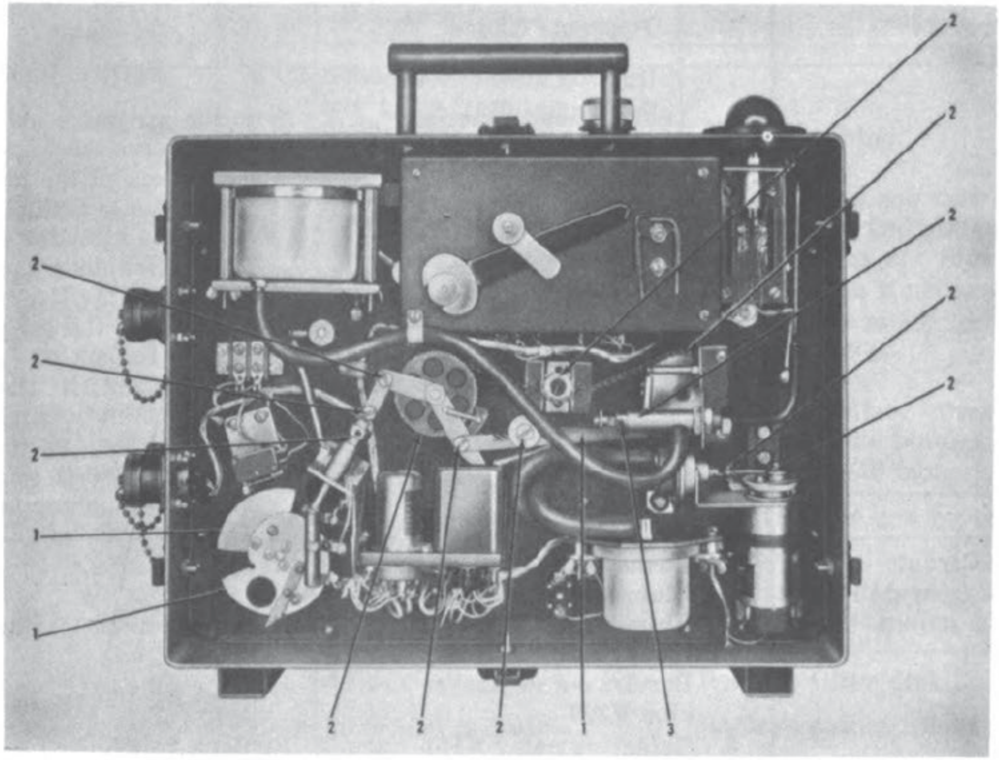

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Figure 13-19.—Lubrication chart for gas alarm.

Point	Lubricant	Spare part kit Item No.
1.	Grease	51
2.	Oil	50
3.	Stop cock grease	52

APPENDIX 1

TRAINING FILM LIST

Training films that are directly related to the information presented in this training course are listed below. Under each chapter number and title, the training films are identified by Navy number and title and are briefly described. Other training films that may be of interest are listed in the United States Navy Film Catalog, NavPers 10000 (revised).

Chapter 1

PREPARING FOR ADVANCEMENT IN RATING

MN 2088A	Discipline — Giving Orders. (15 min.—1943)
MN 3425D	Supervision — Building Morale. (15 min.—1945)
ME 5213A	Problems in Supervision — The Supervisor as a Leader. Part 1 (14 min.—1945)
ME 5213B	Problems in Supervision — The Supervisor as a Leader. Part 2 (13 min.—1945)
MN 5795G	Educational Services — Methods of Teaching. (37 min.—1945)
MN 8165	The Importance of Personal Leadership Today. (28 min.—1954)

Chapter 2

DEFENSIVE TACTICS

MH-8081B	The Marine Rifle Platoon in Offensive Combat—(21 min.—1958).
MA-8746	Guerrilla Warfare — (22 min.—1957—US Army TF33-2509).
MA-9785	Patrolling — (52 min.—1962—US Army TF7-3137).
MA-9842	Rifle Company in Defense — (28 min.—1962—US Army TF7-3120).
MA-9491	Rifle Company as An Advance Guard — (31 min.—1960).
MA-9506	Foot Marches — (23 min.—1960—US Army TF7-2889).
MA-9562	Rifle Squad and Platoon in Defense — (27 min.—1960).

Chapter 3

ELECTRICAL SKETCHING AND PLANNING

SN-34A	T-Square and Triangles—Part 1. 32 frames—B&W—silent—unclassified—1941.)

SN-34B T-Square and Triangles—Part 2. (53 frames—B&W—silent unclassified—1941.)
SN-35A Geometric Construction—Part 1. (40 frames—B&W—silent—unclassified—1941.)
SN-35B Geometric Construction—Part 2. (35 frames—B&W—silent—unclassified—1941.)
MN-37 Behind the Shop Drawing. (16 min.—B&W—sound—unclassified—1941.)

Chapter 4

PROTECTIVE DEVICES AND CONTROLLERS

MN-3485-F Electric Power Afloat-Operating AC and DC Motors and Controllers. (16 min.—1945)

Chapter 5

TESTING EQUIPMENT

SN-2448 Wheatstone Bridge. (59 frames—silent—1943).

Chapter 6

POWER GENERATORS

SN-3485C Electric Power Afloat-Starting and Applying Load. (12 min.—1945.)

Chapter 8

COMMUNICATION

MA 8994A Installation and Operation of Switchboard SB-22/PT. (18 min.—1959.)

Chapter 10

TRAINING

MN 5328-B Shipboard Training Learning by Doing. (13 min.—1949).
MN 6929-A Instructor Training (The Trainee). (10 min.)
MN 6929-B Instructor Training (Subject Matter). (8 min.)
MN 6929-C Instructor Training (The Lesson). (20 min.)
MN 7385-A Using your Voice. (25 min.)
B
C
D

Chapter 13

NBC WARFARE DEFENSE EQUIPMENT

MN 8694-A Radiac Equipment-Meeting Local Needs Ashore. (11 min.—1958)

MN 8694-B Radiac Equipment-Local Care and Maintenance. (10 min.—1959)

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